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PHYSICAL ANTHROPOLOGY

Block

6

HUMAN GROWTH AND DEVELOPMENT

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BLOCK 6 HUMAN GROWTH AND DEVELOPMENT

Introduction

The study of human physical growth and development has been an important part of physical anthropology and human biology since the founding days of these disciplines. Needless to say, this topic has a rich historical tradition of continuous research advancements and accumulation of huge amount of data on physical growth and development of children from human populations inhabiting the globe in diverse physical environments and geographical locations experiencing enormous cultural and socio-economic diversity. Some estimates suggest that systematic studies on growth and maturation dates back to mid-1860s. During that time European anthropology considered the science of body measurements to be a valid tool to assess body dimension and in American Anthropology in the late 19^{th} century, studies on human growth became evident. Since then, the practitioners of physical anthropology in many countries including India, collected data on growth and development of children in time and space dimensions for assessment of growth patterns of children and evaluate factors responsible for such patterns.

Human growth and development is a biocultural phenomenon. It is an important biological process that incorporates a complex interaction among the biological endowment of our species, the physical environment in which this species lives, and the social, economic and political environments that are created by human cultures. Since the basic pattern of human growth and development is common for all human groups, it is considered that this basic pattern is the outcome of the evolutionary history of the hominids, the living humans and our fossil ancestors. The fact mentioned above justifies the interest of the biological anthropologists and the human biologists to undertake research on human growth and development. Furthermore, study of growth and development has an applied anthropological and human biological value in terms of measuring child health and nutrition.

With this backdrop, the four units in this Block are chosen keeping in mind the necessities of understanding the important theoretical aspects of human growth and development. **Unit 1** portrays the basic concepts concerning principles of growth and development, stages of growth before and after birth and characteristic features growth curves pertaining to different parts of the body as well as its organs. **Unit 2** deals with methods of growth studies, merits and demerits of these methods and the occurrence of secular trend in growth profiles of children. Further, it considers the contribution of a variety of factors, viz. genetic, environmental, nutritional, psychological and the like, influencing growth and development. **Unit 3** considers human constitution and physique, and discusses concepts and various methods of somatotyping. Finally, **Unit 4** gives an account of the human reproductive biology, through a discussion on the reproductive physiology of both the sexes, biological aspects of human fertility and other important bioevents concerning maturation in one hand and aging on the other.

We are hopeful that these Units will be a source of motivation to the students to sustain their interest in the topic of human growth and development.

UNIT 1 PRINCIPLES OF GROWTH AND DEVELOPMENT

Contents

Learning Objectives

After going through this unit, you should be able to:

- learn the basic concepts of human physical growth and development;
- understand the patterns of growth from the time of conception through birth, infancy, childhood, maturity, old age; and
- get acquainted with normal growth curves which would help in understanding the growing-up pattern of children and detection of any abnormal physical growth.

1.1 INTRODUCTION

Any parent with grown-up children would have observed the milestones which his or her children have passed as they grew from infancy to childhood, from childhood to adolescence, and from adolescence to adulthood. However, few parents have enough number of children to understand the variation in the rate at which children mature and the relationship which exist between the age at which various maturation processes occur and the end result in terms of adult physical characteristics.

1.2 CONCEPT OF HUMAN GROWTH AND DEVELOPMENT

From the practical point of view, the knowledge of human growth is very important. Those concerned with variations in the physique of adults must know how these physical dimensions are arrived at; the school teacher must know what to expect, physically as well as mentally, from her students as they grow-up; the doctor and nurse must learn to distinguish normal and abnormal growth and know the effects of diseases on growth.

Change is the law of nature. An individual's origin is from a fertilized egg which undergoes the process of growth and development and ultimately turns into a full fledged human adult. This cycle of changes is physical, mental, emotional, etc. Growth and development are important natural processes in an individual.

Growth refers to increase in physical dimensions of an individual, e.g., increase in height, weight, etc. or various parts and organs of the body. It implies increase in size or general bodily growth. The increase is limited by hereditary factors, and influenced by environmental factors, such as, ethnicity, climate, diet and many other factors.

Development refers to enhancement in the functioning of the human body. It entails changes in structure, form, or shape. It takes into account the increase in dimensions, change in proportions and adjustment of parts. Development is evaluated by improvement in the performance of the human body. Development is always gradual, progressive and diversified in form according to different periods of growth.

Very often, the terms 'growth' and 'development' are used interchangeably and considered to be one and the same. Both communicate to the measurement of changes occurring in individuals. The term development includes the perception and process of growth. But strictly speaking growth refers to increase in size and development includes not only growth in size but also functioning of body processes, growth in intelligence, understanding, personality, etc.

Growth can be easily observed, measured, but development cannot be measured easily. Growth stops as soon as an individual attains maturity, but development of an individual is a continuous process throughout life. Growth refers to specific characteristic of the body such as growth in height or arm length, but development is concerned with the entire human body. Infact, for practical purposes these two terms are not always differentiated.

1.3 PRENATAL AND POSTNATAL GROWTH

The entire period of growth can be divided into two major phases, i.e., **Prenatal** (before birth) and **Postnatal** (after birth)**.** The **prenatal** phase is further divided in three distinct stages – the **fertiized egg (ovum) or Zygote**, the **Embryo** and the **Foetus**. The stages of **postnatal** phase are – **infancy**, **childhood**, **adolescence**, **maturity and senescence**.

Prenatal Growth

The period of prenatal growth is significantly important to the child's future well-being; the fact remains that it is the period about which, certainly, we do not have much knowledge. For the first and second trimesters of pregnancy we have to depend on cross-sectional studies. In the second trimester we also have to rely almost completely on foetuses expelled from the uterus because one or the other was abnormal, whereas during the earliest weeks of pregnancy we have mostly normal products of social abortions. For later foetal life we can study infants born prematurely, making the conjecture that these children have grown before birth and will grow after it in exactly the same way as children who remain in the uterus the average length of time, which is in normal cases.

Period of Egg: Fertilized Egg (ovum) or Zygote (first 2 weeks): We do not know what forces are responsible for selecting one out of millions of sperm (i.e. male gamete) which fertilizes the ovum (i.e. female gamete). Fertilization takes

place in one of the tubes which lead from the ovaries to the uterus. The fertilized egg spends some four to five days drifting down the tube and floating in the uterine cavity before it implants into the wall of the uterus (the female organ in which embryo/foetus develops). During this time the cells divide steadily so that at the time of implantation, the blastocyst as it is called consists of around 150 cells. After implantation, the outer layer of the blastocyst undergoes a series of changes which culminate in the formation of the placenta which gives nourishment to embryo/foetus. A small proportion of the inner layer develops into the embryo.

Period of the Embryo (2 to 8 weeks): The period of the embryo is considered to begin 2 weeks after fertilization and ends 8 weeks after fertilization. The child now is recognisably human, with arms and legs, a heart that beats, and a nervous system that shows the beginning of reflex responses to tactile stimuli, is called a **foetus**. At this stage it is about 3 cm long.

This is a hazardous period, and many more ova are fertilized than come to fruition. It is estimated that 10% fail to implant and of those that implant and become embryos half of them are spontaneously aborted, usually without the mother's knowledge. Such abortion is in most cases due to developmental abnormalities, either of the embryo or of its protective and nutritive surrounding structures. 5% to 10% of fertilized ova have abnormalities of the chromosomes but amongst newborns it is only 0.5%. Spontaneous abortions take care of this situation when 90% to 95% of all conceptions with these abnormalities are rejected.

The counting of age in the prenatal period remains problematic. Traditionally, and because we have no better way, age tends to be counted from the first day of the last menstrual period. This occurs on an average 2 weeks before fertilization. Thus the most frequent age at birth is 280 days or 40 weeks, reckoned as 'postmenstrual age', but this represents only 38 weeks of true foetal age. However, there are difficulties in individual cases. The interval from menstruation to fertilization varies considerably; and again, menstrual bleeding may continue in some women for 1 or even 2 months after fertilization.

The velocity is not pronounced in the embryonic period. Initially, during the first 2 months differentiation of the originally homogeneous whole into regions, such as head, arms take place. Histogenesis which is the differentiation of cells into specialised tissues such as muscle and nerve also occurs same time. Each region transforms into a definite shape, by differential growth of cells or by cell migration due to the process called morphogenesis. This carries on until adulthood and in some parts of the body, into old age, though the major part of it is completed by the 8^{th} postmenstrual week.

Period of the Foetus (9 to 40 weeks): As has already been explained reliable growth curves of the foetus are hard to come by. There are reliable data available for body length of foetuses from about 10 to 18 weeks of postmenstrual age, and for infants born prematurely from about 28 weeks onwards. No useful data is available for 18 and 28 weeks. Figure 1.1 shows the distance and velocity curves of body length in prenatal life, and for the first year after birth. The peak velocity is experienced at about 4 month's postmenstrual age. The solid lines shows the actual length and length velocity; the interrupted lines interpret the theoretical curve which is expected if no uterine restriction takes place in the last weeks of pregnancy, followed by a compensating catch-up after birth.

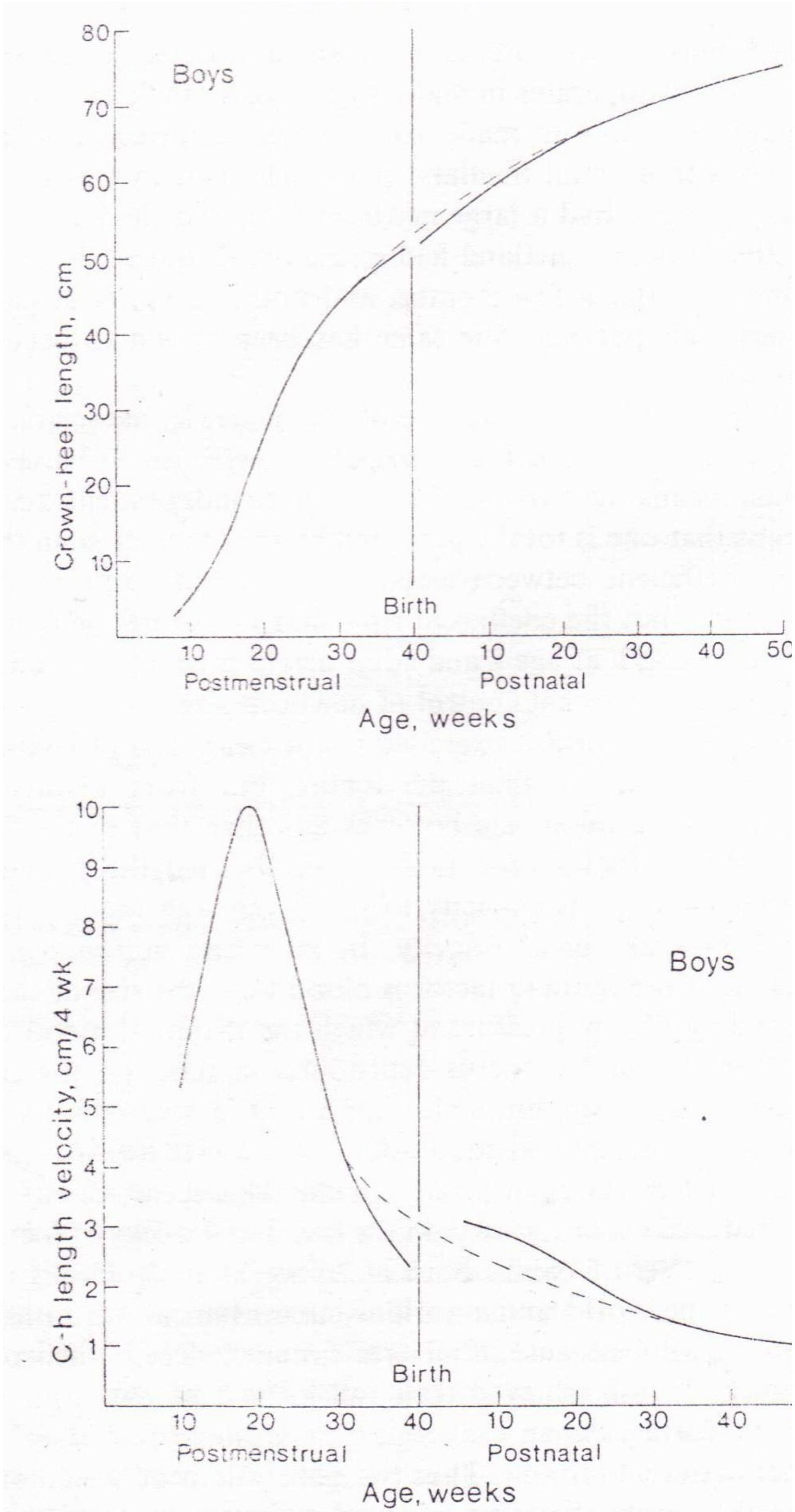

Fig.1.1: Distance (above) and velocity (below) curves for growth in body length in prenatal and early postnatal period

Source: Tanner, J.M., 1978. Foetus into Man: Physical growth from conception to mautrity Cambridge; Harvard university Press

Due to the continuing cellular multiplication the high rate of growth of the foetus takes place compared with that of the child. As the foetus gets older, the proportion of cells undergoing division in any tissue becomes gradually less and it is normally few new nerve cells and only a small proportion of new muscle cells appear after 30 postmenstrual weeks. By this time the velocity in linear dimensions drops sharply. There is however considerable difference in appearance of muscle and nerve cells of the foetus as compared those of the child or adult, due to the fact that early in development there is little cytoplasm around the nuclei. Great deal of intracellular substance and a much higher proportion of water compared to mature muscle are found in foetal muscles, while the later foetal and postnatal growth of muscle comprises primarily of building up the cytoplasm of the muscle cells. Then again salts are incorporated and the contractile proteins are formed as a result the cells become bigger in size, the intracellular substance mainly disappears and the concentration of water drops. This continues fairly vigorously till 3 years and slows down subsequently. It briefly speeds up again in adolescence, particularly in boys, under the influence of androgenic (male determining) hormones. In the foetal nerve cells cytoplasm is added, and the cell processes grow. Postnatal growth for most tissues is significant as a period of development and enlargement of existing cells, while in early foetal life cell division and the addition of new cells takes place.

It is also to be noted that growth in weight in the foetus follows the same general pattern as that of height, except that the peak velocity is reached later, usually at the 34th postmenstrual week. During the last 10 weeks in the uterus, the foetus stores considerable amounts of energy in the form of fat. Up till about 26 weeks postmenstrual age, most of the increase in foetal weight is due to accumulation of protein as the main cells of the body are built up. From then on fat begins to accumulate, both deep in the body and subcutaneously. It has been found that from about 30 to 40 postmenstrual weeks' fat increases from nearly 30g to 430g. Since fat contains much more energy than protein or carbohydrate per unit volume this represents a large reserve of energy available for the first, perhaps critical, period after birth. Conversely, the creation of such a store represents a considerable drain on the energy resources of the mother in the last weeks of pregnancy.

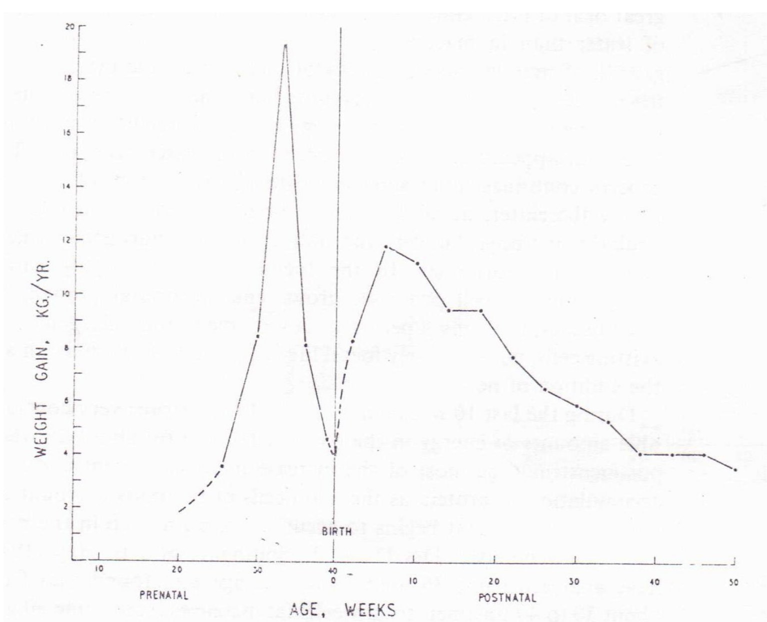

Fig.1.2: Velocity of growth in weight of singleton children

Source: Tanner, J.M., 1978. Foetus into Man: Physical growth from conception to mautrity. Cambridge; Harvard university Press

The Effect of the Uterine Environment on Prenatal Growth: Evidence ascertains that, beginning at 34 to 36 weeks, the growth of the foetus slows down owing to the influence of the uterus, whose available space by that time becomes fully occupied. Twins slow down earlier, when their combined weight is approximately the 36-week weight of the singleton foetus (Tanner 2011). In Figure1.2, a velocity curve is plotted, created before birth from the differences between weight means of singleton babies born alive at periods from 24 to 40 weeks and after birth from differences in weight means in a mixed longitudinal study of a similar population in the U.K. A curve comparable in shape with usual growth curves could be constructed by joining the top, 32-week prenatal point with the first, 8-week postnatal point. Such a hypothetical curve would predict a peak weight velocity reached at about 34 weeks. However, between then and 40 weeks, growth is held up; and the increase in velocity in the first 8 weeks after birth represents a catch-up, on the part of those newborns that have been most delayed in the uterus. Thus, there is a significant negative correlation between length at birth and length gain in the first 6 months after birth, and also between weight at birth and weight gain in the first 6 months. The smaller the baby, on average, the more it grows at this time (Tanner, 1978).

In man it is observed that the correlation coefficient between length at birth and adult height is only about 0·3. Again, the coefficient rises sharply during the first year, and between length at age 2 and adult height the correlation coefficient is nearly 0·8. These figures also reflect maternal control of newborn size. However, it is not clear, how this control is exercised. The placenta grows at first more rapidly than the foetus, but from about 30 weeks onwards its growth rate becomes less than that of the foetus and the placenta/foetus ratio falls. The possibility could be that the placenta simply cannot increase its capacity to supply enough food to sustain the rapid 34-week foetal velocity. In animals like mice and guinea pigs it seems likely that the limiting factor is blood flow, the size of the placenta depending on the pressure at which the maternal blood reaches it, and the size of the foetus depending, in turn, on the size of the placenta. Whether this is also important in man is not yet known.

Poor environmental circumstances, especially of nutrition (inappropriate or low nutrition), result in lowered birth weight in the human being. This seems chiefly to be due to a reduced rate of growth in the last 2 to 4 weeks of foetal life, for mean weights of babies born at 36 weeks to 38 weeks in various parts of the world under various circumstances are rather similar. Mothers who, because of adverse socio-economic circumstances in their own childhood, have not achieved their full growth potential may produce smaller foetuses than they would have done had they grown up under better conditions. Thus, two consecutive generations or even more may be needed to reverse the effect of poor environment on birth weight. In Guatemalan villages, for example, mothers of short stature had babies of lower birth weight than did mothers of medium stature. A food supplement given to the mothers during pregnancy had more effect on the birth weight of children born to short mothers than on those born to medium-sized mothers, but it did not wholly eliminate the difference as observed by Tanner.

So-called 'Premature' Babies: The average length of gestation is 280 days or 40 weeks measured on an average from the beginning of the first day of the last menstrual period. Nonetheless considerable individual variation has also been observed. An international agreement deliberates lengths of gestation from 259 days (or 37 completed weeks) to 293 days (or 42 completed weeks). Babies born within these period are called term babies, earlier to it are called pre-term babies and those born later are post-term babies. Latest studies conclude that the limits of normal term should be between 38 and 41 completed weeks rather than between 37 and 42 weeks.

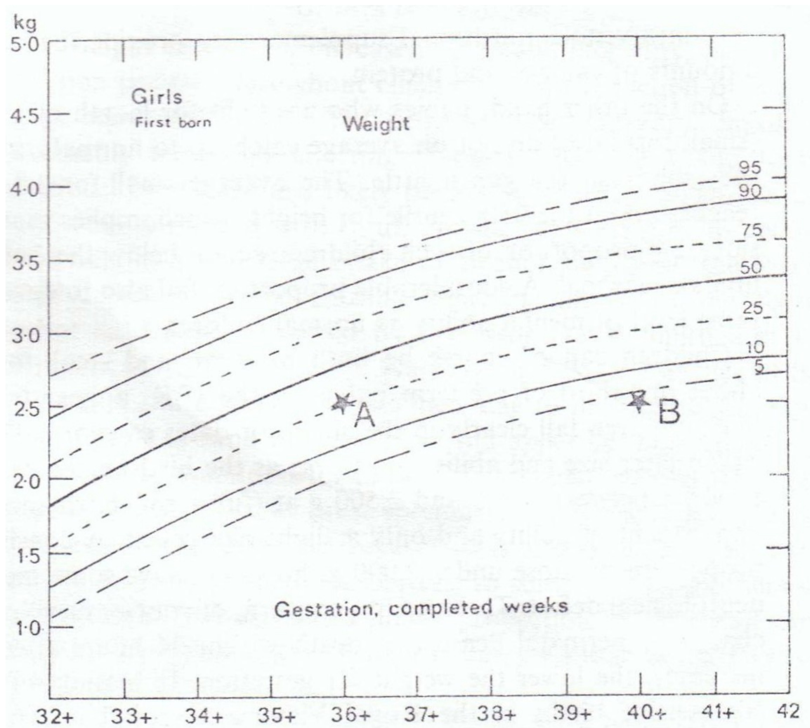

Fig.1.3: Standards for birth weight for gestation age , first born girls.(a) 2,500 g, born at 36 weeks; (b) 2,500 g, born at 40 weeks

Source: Tanner, J.M., 1978. Foetus into Man: Physical growth from conception to mautrity. Cambridge; Harvard university Press

Until a few years ago all babies who weighed less than 2500 g (5½lb.) at birth were designated 'premature' irrespective of their length of gestation or physiological state. This definition as promulgated by World Health Organization in 1948 caused much confusion and has now been dropped; the word 'premature' has disappeared from scientific use. Babies less than 2,500 g at birth according to World Health Organization in 1961 are called 'low birth weight' babies. This low birth weight may be due either to their being born early, or to their being babies who are pathologically small for their length of gestation. The distinction is made by the use of standards such as the one shown in Figure 1.3, which gives the centiles for first-born girls only; children subsequent to the first one are heavier on average by 110 g and boys are heavier than girls on average by 150 g. The baby marked A weighed 2,500 g but was born a month early, at 36 weeks. She is at the 25th centile for first-born girls of this gestational age, thus perfectly normally grown. The baby B, also of 2.500 g, born at 40 weeks (full-term), is below the 5th centile and thus of very questionable normality. Such a baby is known colloquially as 'small-for-dates'.

There exists a tendency for some mothers always to have relatively small babies and other mothers relatively large ones. Therefore, a more critical standard can be constructed in which the weight of the new baby is compared with the birth weight of his brothers and sisters with an allowance given for length of gestation. To a great extent this trait of size at birth runs in families and therefore, is inherited, possibly through characteristics of the maternal uterus rather than of the foetus itself. This variation between families, however, remains strictly within the normal range of birth weights. When we talk about small-for-dates babies we mean those who are beyond these limits. A small overlap exists, for a very few normal babies are necessarily below the arbitrary limit set for the upper bound of small-for-dates infants.

The distinction between pre-term babies of normal weight for length of gestation and babies who are light for their often normal length of gestation is an important one. The purely pre-term infants catch up reasonably well and seem little worse for their earlier experience of the outside world. Even those born as early as 28 weeks weighing 1000 g can be seen these days to grow at the very rapid rate appropriate to their age and sent home 8 to 10 weeks later at the normal weight for a full-term infant. This is possible providing nutritional supplements enriched in nutrients in appropriate quantities.

On the other hand, babies who are light for length of gestation, i.e. small-for-dates, do not on average catch up to normal, although they diminish the gap a little. It is noted that the average small-for-dates child reaches about the 25th centile for height, which implies that a considerable proportion of such children remain below the 3rd centile limits of normal. A substantial proportion fails also to develop the same level of mental ability as normal children.

Children can of course be both pre-term and small-for-dates. About one-third of pre-term babies in the U.K. appear to be so. Such children fall clearly in the small-for-dates category. The deficits in later size and ability get worse as the birthweight decreases. Children between 2,000 and 2,500 g at birth having full-term show little impairment of ability and only a slight size deficit. A considerable proportion of those under 2,000 g, however, have some mental or neurological defect. The chance of perinatal death (i.e. death-within -24-hours after birth) increases. In a study of 44,000 consecutive births in the Royal Victoria Hospital in Montreal, Usher and McLean found that the preinatal mortality was 54 per 1,000 births in babies born at term i.e.37 to 42 weeks with weights under the 3rd centile for gestational age compared with 6 per 1,000 in babies with weights between the 30th and 70th centiles. In babies of all lengths of gestation, perinatal mortality was 16 per 1,000 amongst babies whose weights were between the 3rd and 97th centiles for gestational age, but 189 per 1,000 for those whose weights were under the 3rd centile for gestational age (Tanner, 1978).

Thus, it is documented that the prognosis for a small child born after a normal-length gestation is very different from the prediction for an equally small child born after a shortened gestation. Coming out of the uterus early is not in itself harmful, while growing less than normally during a full uterine stay implies pathology of foetus, placenta or mother.

It is a demonstrated fact that small-for-dates babies are a heterogeneous group, produced by several different causes. In countries where severe maternal malnutrition occurs a proportion of small-for-dates babies are definitely due to maternal malnutrition. But the malnutrition has to be fairly severe, for in this situation the foetus is protected at the expense of the mother. In well-nourished mothers disorders of the placenta may be responsible. Smoking in pregnancy is seen to cause, a reduction of 180 g on average, in full-term foetal weight and a 30% increase in perinatal mortality. The size of reduction persists throughout childhood. This reduction of weight brings some babies into the small-for-dates category. Alcohol appears also to reduce foetal weight, and a large consumption of alcohol may affect the foetus directly. This may cause a recognisable disorder known as the foetal alcohol syndrome. Because of this syndrome, the face of the baby has a characteristic appearance, due to insufficient development of parts around the eyes, nose and upper lip. Some maternal diseases cause smallness-for-dates, in particular rubella (German measles), which also may cause specific deformities and deafness. In other instances it seems the foetus itself is disordered and lacks the capacity to grow properly. According to some studies, mothers of small-for-dates babies have a higher proportion of abnormal outcomes in other conceptions (miscarriages, etc.) than do mothers of normal-sized babies.

Since the worst period for the small-for-dates baby seems to be the last part of pregnancy, when she is, or should be, growing most, many doctors are now advocating removal of these foetuses at 36 weeks, or even at 34 weeks in severe cases. This is done by straightforward induction of labour and vaginal delivery. Much research is therefore in progress to devise means of recognising these foetuses in time for this action to be taken. To date, the most helpful guide to intra-uterine growth insufficiency is measurement of the foetus by ultrasonic means (Tanner, 1978). Ultrasound may be used early in pregnancy to measure the length of the foetus's back from crown of head to rump, and from about 13 postmenstrual weeks to measure the width of the head and the circumference of the abdomen. It seems that screening all babies for crown to rump length between 6 and 12 weeks, for head width between 13 and 20 weeks, and for abdominal circumference at 32 weeks, would detect over 90% of all small-for-dates babies, with a negligible number of false positives (i.e. babies so diagnosed who were really normal). Such a screening programme is well within the capabilities of the medical services of industrialised countries.

Postnatal Growth (birth to maturity)

The amount of growth achieved obviously depends on the time for which growth proceeds and on the speed of growth per unit time. Measurements taken on a single individual at intervals can be plotted against time to produce a graph of progress, whether they are derived from the whole body (e.g. height) or from one of its components (e.g. leg length).

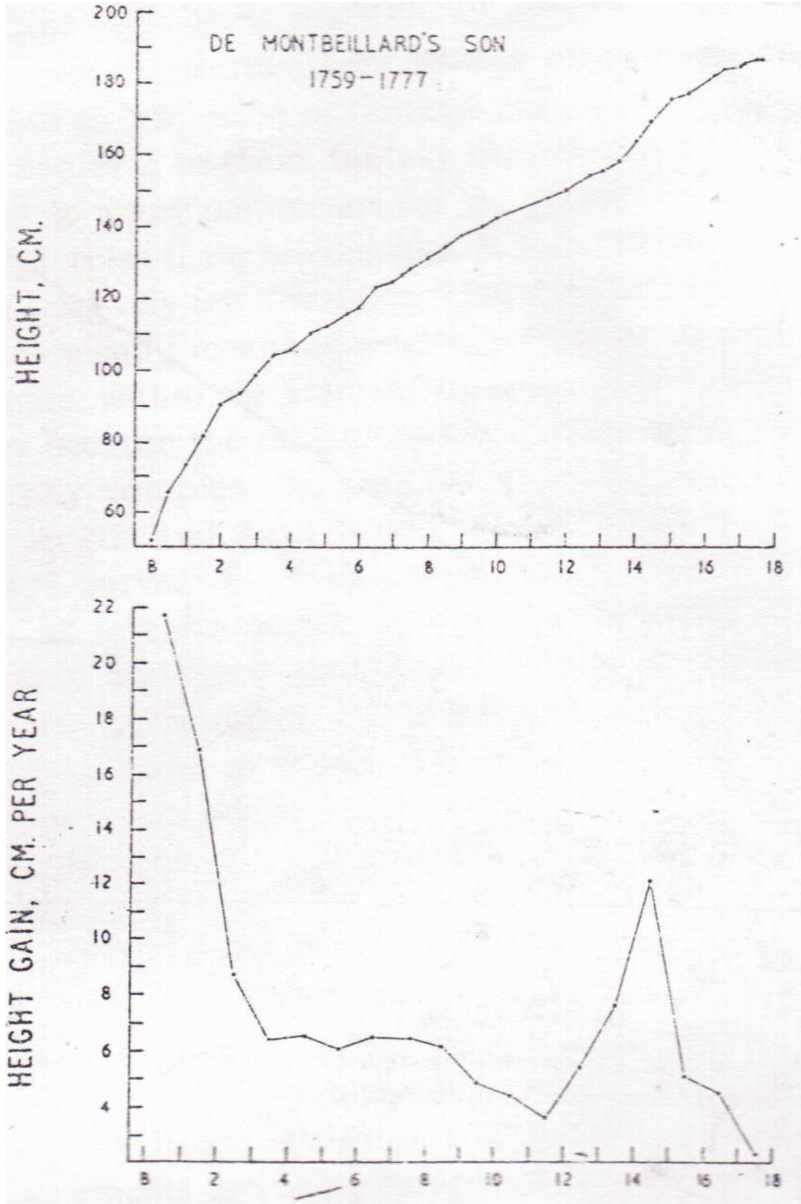

Fig. 1.4: Growth in height of de Montbeillard's son from birth to 18 years; (above-4a) distance curve, height attained at each *year*; (below-4b) velocity curve, increments in height from year to year

Source: Tanner, J.M., 1978. Foetus into Man: Physical growth from conception to mautrity. Cambridge; Harvard university Press

Figure 1.4 shows the most famous of all records of postnatal human growth. It demonstrates the height of a single boy, measured every 6 months from birth to 18 years. This is the oldest longitudinal record in existence, and it remains, one of the best for the necessary illustration. It was made during the years 1759-77 by Count Philibert de Montbeillard on his son and it was published by Buffon in a supplement to the *Histoire Naturelle*.

In Figure 1.4a is plotted the height attained at successive ages while in Figure 4b the increments in height from one age to the next, expressed as the rate of growth per year. If we think of growth as a form of motion and considered analogous to the journey of a train then the upper curve is one of distance traveled and the lower curve, one of velocity. The velocity, or rate of growth, naturally reflects the child's state at any particular time better than does the distance achieved, which depends largely on how much the child has grown in all the preceding years. Thus, for those substances which change in amount with age, the

concentrations in blood and tissues are more likely to run parallel to the velocity than to the distance curve. In some circumstances, it is the acceleration rather than the velocity curves which best reflect physiological events (Tanner, 1978).

Figure 1.4b shows that in general the velocity of growth decreases from birth. From 13 to 15 years in this particular boy, there is a marked acceleration of growth, called the *adolescent growth spurt*. Some writers although distinguish sharply the terms 'adolescence' and 'puberty". Some use puberty to refer to physical changes, and adolescence to refer to psychosocial ones. From birth until age 4 or 5 the rate of growth in height declines rapidly, and then the decline, or in other words deceleration gets gradually less, so that in some children the velocity is practically constant from 5 or 6 up to the beginning of the adolescent spurt. A slight increase in velocity is sometimes seen to occur between about 6 and 8 years. This phenomenon provides a second wave on the general velocity curve, sometimes called as 'pre-adolescent' spurt (Tanner, 1978).

The Adolescent Growth Spurt: The adolescent growth spurt is a constant phenomenon and occurs in all children, though it varies in intensity and duration from one child to another. The difference in size in men and women is to a large degree due to differences in timing and intensity of the adolescent spurt. Before adolescent spurt boys and girls differ only by about 2% in height, but after it by an average of about 8%. The difference is partly because of later occurrence of the male spurt allowing an extra period of growth, and partly because of a greater intensity of the spurt (Tanner, 1978).

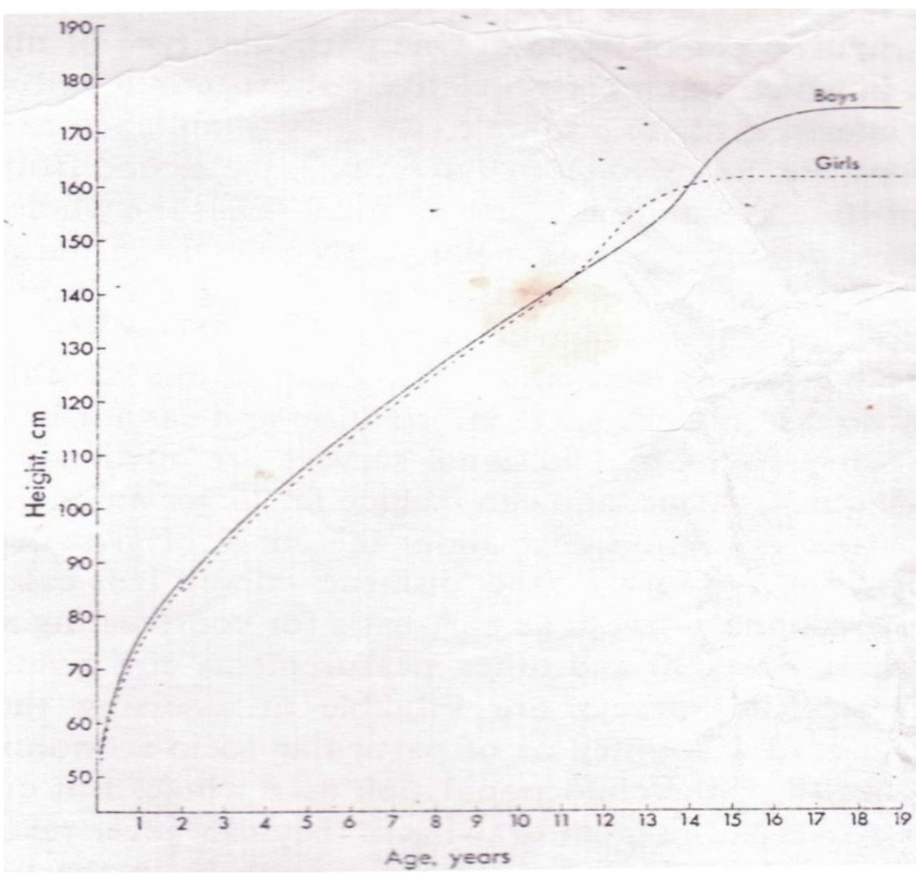

Fig.1.5: Typical individual-height attained curves for boys and girls

Source: Tanner, J.M., 1978. Foetus into Man: Physical growth from conception to mautrity. Cambridge; Harvard university Press

Figure 1.5 shows the typical girl as slightly shorter than the typical boy at all ages until adolescence. She becomes taller shortly after 11·0 years because her adolescent spurt takes place two years earlier than the boys. At age 14·0 she is surpassed again in height by the typical boy, whose adolescent spurt has now started, whereas her adolescence is nearly finished. In the same way, the typical girl weighs a little less than the boy at birth, equals him at age 8·0, becomes heavier at age 9 or 10 and remains so till about age 14·5 (Tanner, 1978).

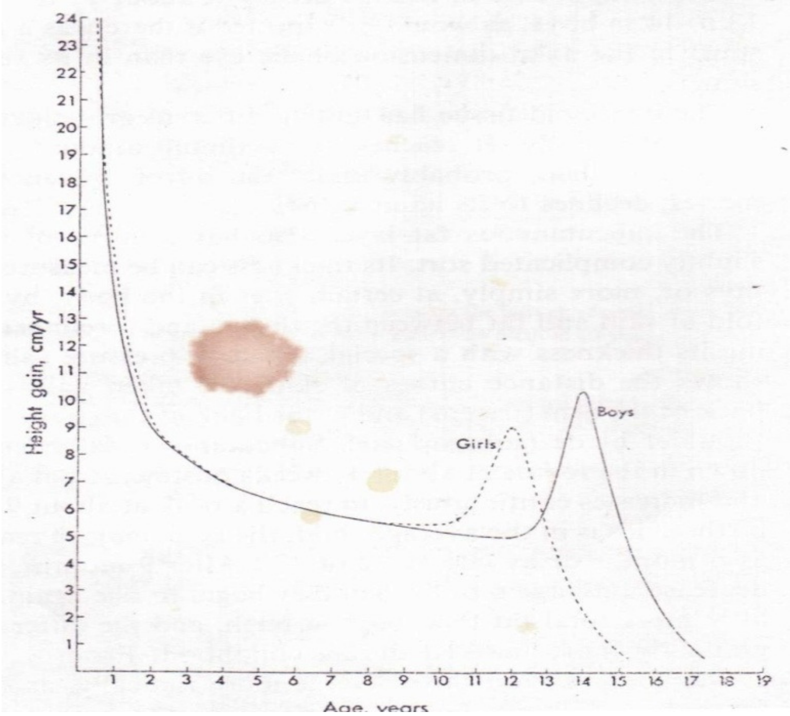

Fig.1.6: Typical individual height velocity height curves for boys and girls

Source: Tanner, J.M., 1978. Foetus into Man: Physical growth from conception to mautrity. Cambridge; Harvard university Press

The velocity curves given in Figure 1.6 show these processes more clearly. At birth the typical boy is growing slightly faster than the typical girl but the velocities become equal at about 7 months and then the girl grows faster until about age 4·0. From then till adolescence no difference in velocity can be detected. The sex difference is best thought of, perhaps, in terms of acceleration, the boy decelerating harder than the girl over the first four years. The typical girl begins her adolescent spurt in height at about 10·5 and reaches peak height velocity at approximately 12·0 in the UK, and about three months earlier in the U.S.A. The boy begins his spurt and reaches his peak just two years later. The boys' peak is higher than the girls', on an average by 10.3 centimeters a year compared with the girls' 9·0 cm/yr as observed in U.K. It is noted that girls are always in advance of boys (i.e. closer to their final mature status), even at birth (Tanner, 1978).

1.4 GROWTH CURVES OF DIFFERENT TISSUES AND DIFFERENT PARTS OF THE BODY

General observations suggest that most body measurements follow approximately the growth curves as described for height. Majority of skeletal and muscular dimensions grow in this manner, and internal organs such as liver, spleen and kidney also follow similar path. But then the brain and skull, the reproductive organs, the lymphoid tissues of the tonsils, adenoids and intestines, and the

subcutaneous fat are exceptions to it. In Figure 1.7 these differences are shown, using the size attained by various tissues as a percentage of the birth-to-maturity increment. Height follows the 'general' curve. The reproductive organs, internal and external, have a slow pre-pubescent growth, followed by a very large adolescent spurt.

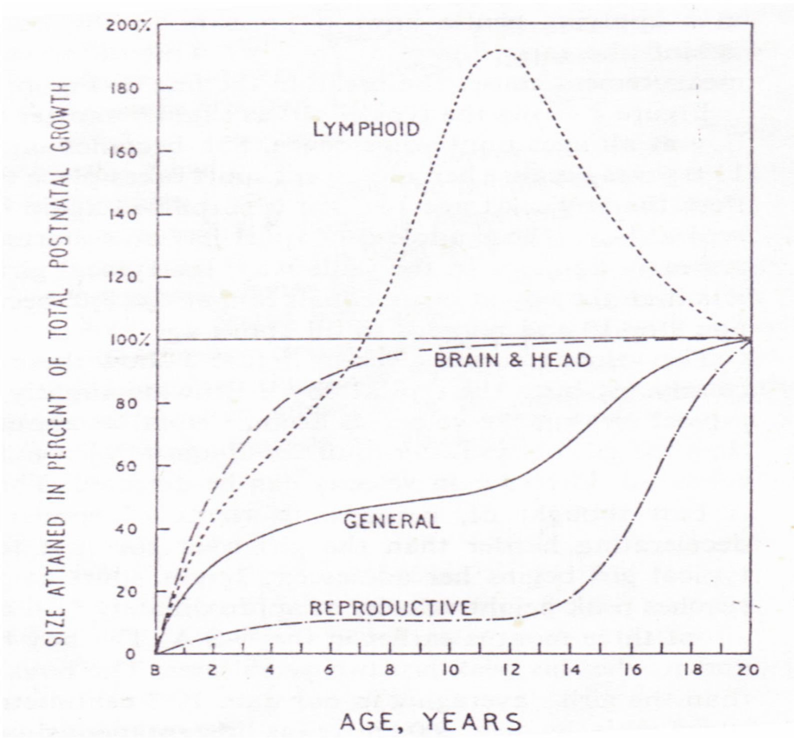

Fig.1.7: Growth curves of different parts and tissues of the body, showing percentage of total gain from birth to 20 years.

Source: Tanner, J.M., 1978. Foetus into Man: Physical growth from conception to mautrity. Cambridge; Harvard university Press

The brain, along with the skull, eyes and ears develops earlier than any other part of the body and thus has a characteristic postnatal curve. The brain experiences a very small adolescent spurt, which is if it occurs. Head length and breadth experience a small but sure spurt, which can actually be attributed to thickening of the skull bones and the scalp, and development of the air sinuses. The dimension of the face is similar to the general curve. There is a significant adolescent spurt, particularly in the mandible, ensuing in the jaw's becoming longer and more projecting, the profile straighter, and the chin more pointed. Nevertheless, substantial individual differences, to the extent that a few children have no detectable spurt at all in some face measurements is also reported.

Eye witnesses a slight adolescent spurt. Though myopia escalates constantly from at least age 6 to maturity, a particularly speedy rate of change happens at about 11 to 12 in girls and 13 to 14 in boys, as would be probable if there was a somewhat greater spurt in the axial dimension of the eye than in its vertical dimension.

It is observed that unlike the rest of the body, the lymphoid tissue has quite a different growth curve from the rest of the body. Generally, it reaches its maximum amount before adolescence and then, possibly under the direct influence of sex hormones, declines to its adult value.

The subcutaneous fat layer also has its particular curve which is somewhat complex. The methods used to measure subcutaneous fat are x-rays or by picking up a fold of skin and fat between the thumb and forefinger and measuring its thickness with a special, constant-pressure caliper referred to as skinfold thickness. Figure 1.8 shows the distance curves of skinfolds taken half-way down the back of the arm (triceps) and at the back of the chest, just below the shoulder blade (subscapular). Subcutaneous fat begins to be laid down in the foetus at about 34 weeks postmenstrual age, and increases continuously, to reach a peak at about 9 months after birth. Usually this is true for an average child. The peak may be reached as early as 6 months or as late as 12 or 15. After 9 months, the skinfolds decrease until age 6 to 8 when they begin to rise again. Girls have a little more total fat than boys at birth, and the difference becomes gradually more marked during childhood. From 8 years on, the curves for girls and boys diverge more radically, as do the curves for limb and body fat. At adolescence the limb fat in boys on average decreases (see triceps, Figure 1.8); the body fat (subscapular) shows a temporary slowing down of gain, but no loss. In girls there is a slight halting of the limb-fat gain at adolescence, but no loss; the trunk-fat shows only a steady rise until adulthood (Tanner, 1978).

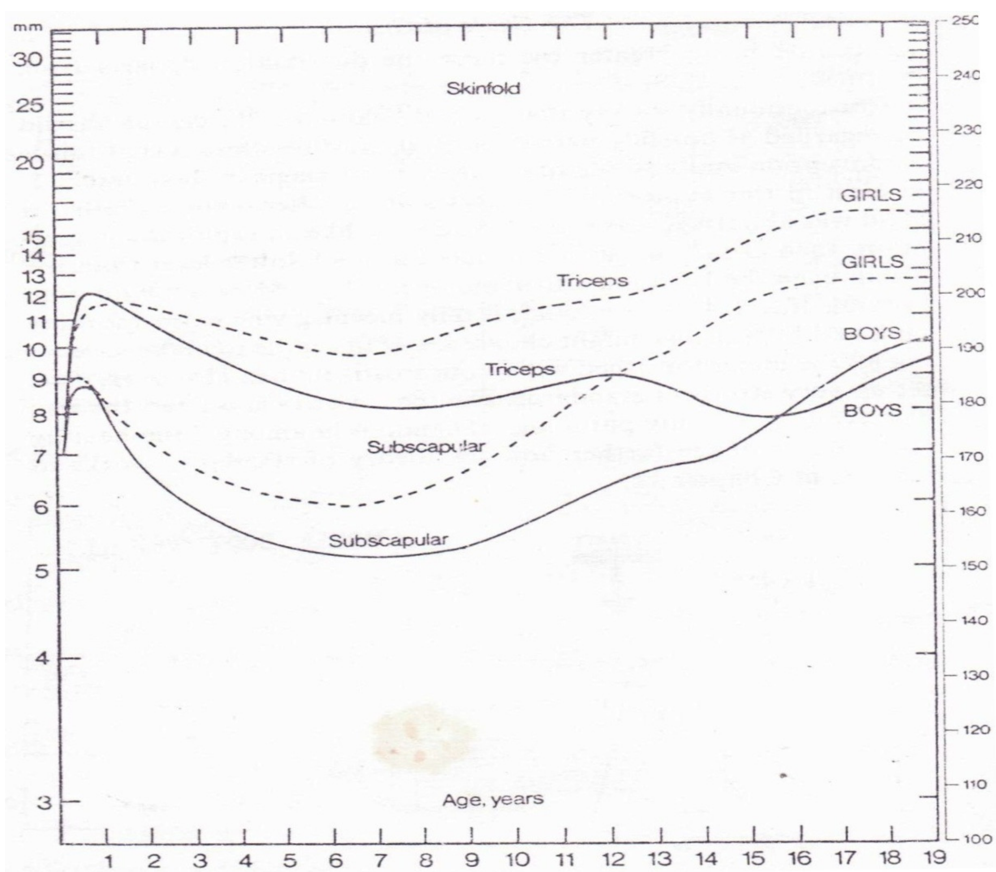

Fig.1.8: Distance curve of subcutaneous tissue

Source: Tanner, J.M., 1978. Foetus into Man: Physical growth from conception to mautrity. Cambridge; Harvard university Press

Post adolescent Growth: Growth, even of the skeleton, does not entirely cease at the end of the adolescent period. The limb bones stop increasing in length, but the vertebral column continues to grow until about age 30 years, by apposition of bone to the tops and bottoms of the vertebral bodies. Thus height increases by a small amount, on average 3 to 5 millimeters. From about 30 to 45 years height remains stationary, and then it begins to decline. Head length, head breadth and facial diameters increase slightly throughout life. The widths of the bones in the leg and in the hand, in both sexes also increase. For practical purposes, however, it is useful to have an age at which we may say that growth in stature virtually ceases, i.e. after which only some 2% is added. At present in the developed nations such as North America and north-west Europe, the average boy stops growing, in this sense, at 17·5 years and the average girl at 15·5 years. There is a normal range of variation amongst individuals, amounting to about two years, on either side of these averages.

Senescence: The one thing in life that is certain to occur is – death. It may be sooner or later, and the manner in which it occurs may vary considerably. As one grows older the chances are that death will be preceded by a varying period during which the physical or mental faculties, or both, become gradually reduced. It is these processes followed by death, which is called senescence. Senescence could also be defined as including those effects which lead to a decreased expectation of life as the age increases. We can measure senescence by finding the death rate in a population. Senescence can be influenced by genetic as well as environmental factors. The genetic component of senescence can be studied by inheritance of longevity, which may be due to absence or presence of predisposition to disease. The classical method of genetic analysis using twins also gives interesting information. The difference in age at death between monozygotic (identical) twins is only half of that between dizygotic (non-identical) twins. But the correlation between ages at death of siblings is twice that between parent and child. This suggests that environmental factors may also be of importance. For example, lung cancer is a senescent disease, whether caused by excessive smoking or atmospheric pollution, it is largely environmentally determined.

1.5 SUMMARY

Growth refers to increase in physical dimensions of an individual, e.g., increase in height, weight, etc. **Development** refers to changes in structure, form, or shape; it includes increase in dimensions, change in proportions and adjustment of parts; and provides improvement in the functioning of the human body. Growth and development are influenced by hereditary and environmental factors.

The entire period of growth can be divided into two major phases, i.e., **Prenatal** (before birth) and **Postnatal** (after birth). The **prenatal** phase is further divided in three stages – **the fertilized egg (ovum) or zygote, the embryo and the foetus.** The stages of **postnatal** phase are – **infancy**, **childhood**, **adolescence**, **maturity**, **senescence**.

Prenatal Growth

Fertilized egg (ovum) (first 2 weeks) is the period when formation of placenta and embryo occur.

Embryo (2 to 8 weeks) is the phase when the differentiation of the originally homogeneous whole into regions, such as head, arms and so forth occurs, due to the differentiation of cells into specialised tissues such as muscle and nerve. Simultaneously, each region is transformed into a definite shape, by differential growth of cells or by cell migration by the process morphogenesis. At the end of this period it is 3 cm long.

Foetus (9 to 40 weeks): At the beginning of this period the child is recognisably human, with arms and legs, a heart that beats, and a nervous system that shows the beginning of reflex responses to tactile stimuli, and is called a foetus. The growth of height and weight follow similar increasing pattern, except that the peak for height is reached at about 16 postmenstrual weeks, while that of weight is reached at about 34 postmenstrual weeks. Up till about 26 weeks postmenstrual age, most of the increase in foetal weight is due to accumulation of protein, but from then on fat begins to accumulate. There is an increase in fat from 30 to 40 postmenstrual weeks from some 30 g to 430 g. Since fat contains much more energy than protein or carbohydrate per unit volume this represents a large reserve of energy available for the first, perhaps critical, period after birth.

The Effect of the Uterine Environment on Prenatal Growth: By the time the foetus is 34 to 36 weeks the growth slows down due to the influence of the uterus, whose available space is by then becoming fully occupied. This facilitates a child to be successfully delivered. As a result of poor environmental situations, especially of nutrition, lower birth weight is observed.

So-called 'Premature' Babies: Measured from the first day of the last menstrual period, the average length of gestation is 280 days or 40 weeks. Term babies born within 38 and 41 completed weeks are babies less than 2,500g at birth 'Low birth weight' babies (earlier known as 'premature' babies). The prognosis for a small child born after a normal-length gestation is very different from the prognosis for an equally small child born after a shortened gestation. Leaving the uterus early is not in itself harmful, but then growing less than normally during a full uterine stay reflects pathology of foetus, placenta or mother.

Postnatal Growth

From birth onwards children grow steadily, however, the rate of growth in height gradually declines from birth till age 4 or 5 years, and then it almost remains constant till beginning of the adolescent spurt. A slight increase in velocity sometimes occurs between about 6 and 8 years, called as 'pre-adolescent' spurt.

The Adolescent Growth Spurt: Adolescent growth spurt is a constant phenomenon experienced by all children. The timing and intensity of the adolescent spurt is depicted in the difference observed in size in men and women. 2% of height difference is observed in boys and girls before adolescent spurt but increases to an average of 8% after the spurt. Generally girls are shorter than boys at all ages till they reach adolescence. But, girls grow taller after 11 years because adolescent spurt is two years earlier than in boys. By the time she is 14 years a typical boy again overtakes in height. This is because of the onset of adolescent spurt in boys while in girls it is nearly finished. Similarly, as for weight, a girl is lighter at birth, equals at 8 years, heavier at age 9 or 10 and remains so till about age 14·5.

Growth Curves of Different Tissues and Different Parts of the Body: Most body measurements follow approximately the growth curves described for height. The great majority of skeletal and muscular dimensions grow in this manner, and so also do the internal organs such as liver, spleen and kidney. The reproductive organs, internal and external, have a slow pre-pubescent growth, followed by a very large adolescent spurt. The brain, together with the skull covering it and the eyes and ears, develops earlier than any other part of the body and thus has a characteristic postnatal curve. The curve for lymphoid tissue reaches its maximum amount before adolescence and then, probably under the direct influence of sex hormones, declines to its adult value. There is a continuous increase in subcutaneous fat with peak at 9 months after birth. Subsequently, there is a decrease in skinfold until 6-8 years after which it starts increasing again. Gender difference is observed with girls having little more fat than boys at birth; this difference becomes more vivid during childhood.

Postadolescent Growth: Growth, does not entirely cease at the end of the adolescent period. Though, the limb bones stop increasing in length, but the vertebral column continues to grow until about age 30 years, by apposition of bone to the tops and bottoms of the vertebral bodies. This results in increase of height by a small amount, on average 3 to 5 millimeters.

Senescence: It is the process of becoming old. This stage starts from complete maturity to death witnessed by accumulation of metabolic products, decline in function and decreased potentiality for reproduction and survival.

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Suggested Reading

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Sample Questions

1) What does the study of 'growth' and 'development' deal with? Explain the effects of uterine environment on prenatal growth.

2) Write an essay on various stages of postnatal growth of children.

3) Describe adolescent growth in children highlighting sex differences.

4) Describe growth curves of different tissues and parts of the body.

5) Short Notes: (i) Growth and Development (ii) Embryo (iii) Premature babies (iv) Small-for- date babies. (v) Adolescent growth spurt (vi) Postadolescent growth (vii) Senescence.

UNIT 2 METHODS AND INFLUENCING FACTORS

Contents

Learning Objectives

After going through this unit, you should be able to

- understand the longitudinal, cross-sectional and mixed-longitudinal methods of studying growth;
- define and describe "Secular trends" as observed in different populations;
- describe growth gradients as observed in different segments of human body;
- understand the concept of catch-up growth; and
- understand and describe the influence of genetic, biochemical and environmental factors including nutrition, disease, socio-economic status, urbanization, seasonal and climatic variations and psychosocial stress on human growth and development.

2.1 INTRODUCTION

We feel extremely happy while introducing you to the fascinating study of human growth and development with special reference to its methodology and various factors affecting it. Let me tell you that the process of human growth and

development which takes almost twenty years to complete, is a complex phenomenon. To have a complete understanding of this process we must have the knowledge about various methods of studying it, along with their advantages and disadvantages. Both genetic and environmental factors influence human growth and development. Every child acquires his genetic potential for a particular adult size and shape from his parents and realises this potential when the environment supports the genetic model that regulates development. The term "genetic potential" usually means that every human being has a genetically determined upper limit for adult stature, the ratio of leg length to sitting height and other anthropometric dimensions/ ratios. Growth can be impaired when there is a negative influence of the environment i.e. the child is suffering from malnutrition or illness, or hormonal deficiency etc. However, the ability of environmental influences to alter genetic potential depends on a number of factors including the time at which they occur; the strength, duration and frequency of their occurrence and the age and gender of the child. Therefore, it is extremely important to have a clear understanding of how children grow under different circumstances. What are the factors which influence human growth and development? What is the velocity of growth of a child during recovery after the nutritional stress (concept of catch-up growth)? What is the sequence in which different segments of our body attain maturity (growth gradients)? It is a well documented fact that children have been getting larger and growing to maturity earlier over time in both developed and developing countries. This has been referred to as "secular trends." We must know about the causes for secular trends observed in different populations.

In this lesson you will get answers to all these questions raised above. We are going to learn in detail about various methods of studying human growth and development along with their advantages and disadvantages. What do we mean by secular trends? What do we understand by catch-up growth? What are growth gradients? What is the role of genetic and environmental factors in regulating human growth and development? The knowledge of all these aspects is very important because of their implications in public health. Data gathered through different methods of studying growth are used to establish growth standards or norms of a population. Growth of children can be monitored using these standards. With the help of such studies we are aware of the relationship between growth and need for proper environment. We may change our children's diets according to the requirements for specific ages, which may lead to their improved growth status. An attempt has been made to make you understand these important aspects with the help of suitable examples wherever required to inculcate interest in this subject.

2.2 METHODS OF STUDYING GROWTH

A well designed growth study is a prerequisite to monitor the health status of a population. Rigorous thought should precede collection of data, regarding method of study, time and cost involved with precise planning of sampling procedures, careful training in anthropometric measurements and statistical methods to be used for data analysis. In order to gain an understanding of the dynamics of human growth and average growth patterns it is essential that the appropriate methods are selected. Auxologists, anthropologists, nutritionists and health professionals use precise methods of studying human growth while conducting

growth surveys of children in different populations. The most commonly employed methods by researchers to obtain age and sex specific growth data are either cross-sectional or longitudinal. Both types of methods are required for a full understanding of the growth process. These methods have been described below:

Cross-sectional method

Human growth can be studied using cross-sectional method, which involves measuring children only once during the entire span of the study. In this method for example, all the children being measured by an investigator at age 9 are altogether different from those at age 8, which in turn are different from children being measured at 7 years and so on. In other words, the method of study using different children at each age is called cross-sectional. In this method there is no element of periodic assessment. Cross-sectional surveys provide information about the distance curve of growth of any dimension of the body.

Advantages

Cross-sectional methods are obviously cheaper, less time consuming, can include much larger number of subjects in a brief duration and provide important information about the distance attainments or gross size attained by children during a span of time (e.g., on average, a newly born child attains 10 kg of weight and 78 cm. of supine length at 1 year of age.). This method is very useful for constructing growth standards for communities. Cross-sectional surveys are valuable in assessing the nutritional status and health related problems of children prevailing in different communities at any given point of time.

Disadvantages

The major drawback in cross-sectional studies is that they can never reveal individual differences in rate of growth (i.e. growth velocity) of different body dimensions of children, since in this method we measure each child only once without any periodic follow up. In fact, it is these individual differences which reflect the cumulative effect of various genetic, environmental, hormonal, nutritional, psychological, and socio- cultural factors on human growth. Moreover, cross-sectional data do not provide precise information about timings of particular phases of growth like onset of "Juvenile growth spurt" attainment of "Peak height velocity" , "Peak weight velocity" etc. Though they give us an estimate of the mean rate of growth of a population (by subtracting the mean height at 8.0 e.g., from that at 9) they tell us nothing about variability around that mean. Therefore, as a caution, we should not compute "growth velocity" of any body parameter based on cross-sectional data.

Discuss various methods of studying human growth giving their merits and demerits.

Longitudinal Method

The method of study using the same child at each age is called longitudinal method. In this method of studying human growth every child enrolled in the study is periodically measured for one or many body measurements at fixed intervals of time throughout the period of study. All children, say measured at age 5.0 years will remain the same as those who were examined at 4.0 years. Constancy of sample size and strict adherence to stipulated periodicity at which

children are to be followed up remain the most important prerequisite of this method. A growth study may be longitudinal over any number of years. To obtain the simplest type of velocity standards, individuals have only to be measured twice i.e. once in a year. There are short term longitudinal studies extending from age 3 to 6 for instance and full birth to maturity longitudinal studies in which children may be examined once, twice, quarterly or even more times every year from birth until 20 years or more depending upon the objective of the study. However, in practice, due to various reasons it is not possible to measure exactly the same group of children for a prolonged period.

The main drawback of a comprehensive longitudinal study is that it takes a long time to complete and relatively small number of subjects can be followed. To overcome these problems, 'Linked longitudinal studies' are undertaken i.e., studies covering the ages 0 to 6, 5 to 11, 10 to 15, 14 to 20 years. Through this design within a period of six years, whole age range of growing phase of human life is spanned. However, efficient sampling of the population is crucial to obtain smooth joins of the data collected during short intervals. For an intensive investigation of the relation between continuously unfolding events in individuals and very often for clinical investigations of growth disorders, long term longitudinal studies even from birth to maturity are necessary. We need to use appropriate statistical methods while working out the results of each type of study.

Advantages

Longitudinal studies besides providing information about the distance (gross size), growth attainments also provide growth velocity related data i.e., about individual rate of growth measured by increment between two successive periods. Such studies also tell us about the timing of particular phases like 'onset of juvenile growth spurt' or 'adolescent growth spurt' of individuals. As the growth velocity denotes inherent capacity of a child to grow and develop, so these studies help to understand the influence of genetic and environmental factors on the growth dynamics of children.

During childhood we often have illnesses which are short-termed. Longitudinal studies provide opportunity to have information about the duration of any disease or nutritional insult with which any child might have remained afflicted with for a longer period. Similarly, effect of intervention (medical/nutritional etc.) may also be assessed with the help of these studies as children included in such surveys are often monitored periodically.

Disadvantages

i) Longitudinal studies are very expensive and require great skills to organise.

ii) Studies are very laborious and time consuming. These studies require patience, perseverance and motivation on the part of both subjects as well as researchers who undertake it. The researchers have to stick to the already planned periodic schedule during the entire duration of the study, which at times becomes difficult to adhere to because of certain compelling circumstances.

iii) Longitudinal studies involve examination of limited number of children. It is not always possible to maintain consistency of sample size throughout the entire span of study. Many subjects leave the study as they move to new places because of social as well as occupational reasons.

Mixed-Longitudinal study

A serial study in which a group of children is followed such that some children leave the study and others join it as new entrants at different ages, giving various degrees of longitudinally is termed as mixed longitudinal study. On one end such a study results in accumulation of data with missing values, on the other hand this design provides an opportunity to make up for the simple loss by enrolling new subjects at any requisite age points. Mixed-longitudinal studies are relatively cheaper to conduct and also less time and effort consuming as compared to pure longitudinal studies. These studies also provide us with both distance and velocity curves, however, estimation of growth velocity of different body parameters from mixed longitudinal data involving missing values is a tedious task and special statistical methods are required to get relevant information out of such data. In some circumstances the manipulation of increments derived from each individual measured twice or more is reasonably efficient and simpler. The means of such increments may be used to calculate more efficient measurement-at-given age or distance means at successive ages.

2.3 SECULAR TRENDS

Over the past hundred years in industrialised countries, and recently in some developing nations, children have been getting larger and growing to maturity more rapidly. This has been referred to as 'the secular trend' in growth. In other words, the acceleration or retardation of growth and maturation as indicated by changes in height, weight or other variables over time is called secular trend. Many factors such as improved nutrition, control of infectious diseases through immunizations and sanitation, widespread health and medical care, better living conditions, changes in environmental and socio-economic factors, population mobility (both geographically to urban areas and socially upward) may account for increase in body size and biological maturation resulting in secular trends. On the other hand wartime deprivations or natural calamities like famine, tsunami may cause a decrease in growth.

The occurrence of a secular increase in height and weight has been well documented from many European countries like, Sweden, Finland, Norway, France, United Kingdom, Italy, Germany, Czechoslovakia, Poland, Hungry, the Soviet Union, the Netherlands, Belgium, Switzerland and Austria. From the rest of the world there are reports from Canada, the United States, Jamaica, Chile, Australia, New Zealand, Japan, Hong Kong, China, Sechychelles and India showing increase in height and weight over decades. Even the adult height of Kalahari Bushmen in South Africa and Australian Aborigines has shown an increase due to a more settled existence from the traditional hunting and gathering life. The average secular increase in height in Europe and North America is greatest during adolescence (2 to 3 cm. per decade), less during childhood (1 to 2 cm. per decade) and least for adults about 1cm per decade or less. Comparable changes have been occurring in weight and other body dimensions. Secular trend in birth length has also been observed in new born babies. Studies have noticed rising trends in 11 European countries. Rates of 30 mm. per decade have been achieved in Eastern Europe and Japan.

There has also been a secular change in the tempo of growth as is shown by an advancement of age at menarche and age at peak height velocity. Maturation has

been getting earlier during the last hundred years by 3 to 4 months per decade in most European countries. This trend is slowing down now in developed countries, both in body size as well as in maturation. Recent studies have shown that the increase has reached a plateau in countries like Germany and Poland due to the fact that the corresponding populations had achieved their full genetic potential or that their socio-economic conditions had ceased to further improve. Its magnitude is such that in Europe, America and Japan it has dwarfed the differences between occupational groups. In developing countries due to continuous improvement of living standards, nutritional and health care, the secular trend in various biological parameters is still observed. In India studies have reported positive secular trends in height among high altitude Himalayan populations over last three decades. A comparison in the heights and weights of Punjabi boys from Patiala between 1950 and 1975 showed a negligible average increase in magnitude of stature from 1950 to 1955, from 1955 to 1965 there is an increase of 2.20 cm. and from 1965 to 1975 it is 4.90 cm. per decade. In the total period of 25 years, an overall increase of 7.45 cm. has been noticed giving an increment of height of 2.98 cm. per decade and for weight of 1.48 kg. per decade.

In three decades i.e., from 1962 to 1991 the age at menarche in Maharashtrian girls has lowered by two years. Among Bengali Hindu girls a decrease of 5-7 days per annum was observed. In general, girls from upper socio-economic group experience menarche earlier than the girls from lower socio-economic status. Reports on stature and age at menarche of Punjabi Arora mothers and daughters from Delhi also show a substantial increase in stature of daughters and an advanced age at menarche as compared to their mothers indicating secular trends towards increase in height and decrease in age at menarche.

Secular trends in growth in terms of the narrowing of ethnic differences in stature have been discussed in some studies. Asiatic populations' seen since 1990 are much more comparable in stature to their counterparts to a different place in the world. A comparable evaluation among affluent adolescents illustrates Asiatic populations to experience earlier onset of pubertal growth spurt in stature than other major populations but have similar peak height velocities. Studies on secular changes in height and weight in populations are invaluable as they give information on nutritional status in early life, evaluating the growth reference standards and providing perception with regards to epidemiological trends of lifestyle diseases.

2.4 GROWTH GRADIENTS

The bodily proportions of a child change with the advance in age. An estimation of this change provides a measure of maturity. It is well known that different parts of the human body grow at different rates and the sequence of their reaching adult size also differs from one segment to another. One way in which the organization of growth shows itself is through the presence of maturity gradients. To explain it let us take the example of foot length, calf length and thigh length in boys. When we plot the percentage of the adult value at each age for foot length, calf length and thigh length, we find that the foot is nearer its adult status than calf, and the calf is nearer than the thigh. Thus, our foot gets matured fastest, followed by calf and thigh is the last in the sequence to achieve adult value. A maturity gradient is said to exist in the leg, running from advanced maturity distally to delayed maturity proximally. Similar gradient occurs in the upper

limb, where hand achieves its maturity status earlier than forearm, which in turn, acquires maturity earlier than upper arm. Moreover, girls are more advanced in maturity at all ages than boys but the sequence of maturity in them remains the same i.e. the-distal proximal gradient.

What are different types of growth gradients observed in different segments of our body?

Many other gradients exist, some covering small areas only and operating for short periods, others covering whole systems and operating throughout the whole of growth. The head, for example, is at all ages in advance of the trunk, and the trunk in advance of the limbs. This type of gradient is called cephalo-caudal gradient. From early foetal life onwards the brain, in terms of its gross weight is nearer to its adult value than any other organ of the body, except the eye. At birth it is about 25 per cent of its adult weight, at 6 months nearly 50 per cent, at two and a half years about 75 per cent, at 5 years 90 per cent and at 10 years 95 per cent. This contrasts with the weight of the whole body, which at birth is about 5 per cent of the young adult weight and at 10 years about 50 per cent. Growth gradients are easy to compute. Percentage of the adult value can be easily calculated for each age group under study and plotted in a graph against each age group.

2.5 CATCH-UP GROWTH

The term catch-up growth refers to the acceleration seen in many children during recovery from serious illnesses or from environments that retard growth. Two conditions are necessary for this designation

i) growth retardation as shown by previous low percentile levels of measures and

ii) subsequent increase in these percentile levels.

It has been well documented that whenever a child suffers for a short period of time from an illness or starvation he/she is able to return to his regular course of growth, when conditions improve due to proper treatment given for the respective problem. In doing so his initial growth velocity after recovery is unusually large (higher than normal) than expected of children of his age. Such a higher than normal velocity has been named 'catch-up growth' by Prader, Tanner and Von Harnack in 1963. For example, if there are three children suffering from different problems, first child from malnutrition, second from hypothyrodism and third from cortisol producing tumour (growth-inhibiting), all three will show growth retardation. However, when all three children get completely treated for the respective conditions, then during recovery catch-up growth will occur in all of them. The velocity during the initial period of catch up may reach three times the normal for age, where after, it slows down to its normal velocity. The power to stabilize and return to a predetermined growth curve after being pushed off the trajectory is called by Waddington 'canalization' or homeorhesis (homeostasis being the maintenance of a static condition and homeorhesis being the maintenance of a flowing or developing one). The effect of unfavourable conditions on growth seems to depend upon the duration and the severity of the insult and age at which it occurs. Catch-up growth may completely restore the

situation to normal or it may be insufficient to do so. In less favourable circumstances where treatment is incomplete or less effective, the child may resume growth at a normal, but not higher than normal velocity. The result of this may still be satisfactory, since if skeletal maturation is delayed, as is usual in such circumstances, the growing period will be extended and thus the final height will be close to normal, though reached late.

2.6 GENETIC FACTORS INFLUENCING GROWTH AND DEVELOPMENT

Children tend to resemble their parents in stature, body proportions, body composition and rate of development. It may be assumed that barring the action of obvious environmental influences (such as chronic illness or long term malnutrition) these resemblances reflect the influence of genes that parents contribute to their biological offspring. The term "genetic potential" usually means that every human being has a genetically determined upper limit to adult stature, the ratio of leg length to sitting height and other anthropometric dimensions. An individual may achieve this genetic potential if the environment is free of insults that delay or retard growth. The child's development may be shunted from one line to another in a situation when a particular environmental stimulus is lacking at a time when it is necessary for the child. It is inferred that the ultimate size and shape that a child attains as an adult is the result of a continuous interaction between genetical and environmental influences during the whole period of growth.

Discuss the role of genetic factors in regulating human growth.

Now let us understand the role and importance of genetic factors in regulating human growth. Genetic factors are clearly of immense importance. Factors affecting the rate or tempo of growth must be considered separately from factors affecting the size, shape and body composition of a child. The genetical control of tempo seems to be independent of genetical control of final adult size, and to a large extent of final shape. Environmentally produced changes in tempo do not necessarily seem to be separately controlled by genetical and environmental factors. The genetical control of shape is much more rigorous than that of size, presumably because shape represents chiefly how the cells are distributed, while size represents more the sum of sizes of the various cells.

The most striking similarity in growth is seen in monozygotic twins, who share the same genes and most aspects of the family environment. Siblings share fewer genes and possibly few aspects of family environment also, but resemble each other a great deal more than unrelated children. Family patterns of growth exist, and closer the genetic relationship, the closer in general the growth pattern. This is probably because growth and adult size and shape are controlled by numerous genes, each of small effect, rather than by few major genes. Data on monozygotic twins (MZ) reared together and apart have been reported by Shields (1962). Those reared apart were more different in adult stature than those reared together, but they were more similar than dizygotic (DZ) like- sexed twins. Shield illustrates some individual cases of MZ twins reared apart where one twin was subject to illness or neglect, showed considerable differences in size, showing the over-riding effect of a poor environment.

Tempo of growth in height from birth to 4 years has been studied in twins in the longitudinal Louisville Twin Study. The analysis of the growth curves indicated a strong genetic control of the rate of growth and especially, in change in rate. Studies of the resemblance of siblings at the same age have been reported by Garn and Rohmann (1966). In general correlation co-efficient of body length measures between siblings are of the order of 0.3-0.5, though in some measurements sister-sister values are higher than brother-brother ones. Siblings are also highly correlated in birth weight, but this is mainly due to maternal uterine factors.

The resemblance of body measurements between parents and children is also marked, though not before the children are of about 2 years and showing more effect of their own genes than the effect of uterine environment in which they grew. From 3 to 9 years correlation coefficients of height between parents and offspring are slightly under 0.5 and have been made the basis of standards for childhood height allowing for height of the parents. There is little evidence that on average one parent predominates in their effect on size, or that sons resemble fathers and mothers daughters more than conversely. When the parents' height is known, the range of variation in adult height, represented by ± 2 standard deviation of the mean is from 25 cm. in the general male populations to 17 cm. in a given family, 16 cm. among brothers and 1.6 cm amongst monozygotic twins reared together. At the same time length of limbs and trunk are also under genetic control, while skeletal breadths and of course fat are less so.

Not only is physical size heritable but the timing and tempo of maturation also are significantly controlled by genes. The genetical control of tempo of growth is best shown by the inheritance of age at menarche. Monozygotic twin sisters growing up together under best conditions reach menarche on an average 2 months apart, whereas dizygotic twins differ on average by 12 months. The sister-sister and mother-daughter correlations are close to 0.50, indicating high degree of genetic determination of age at menarche. Thus, a large proportion of the variability in age at menarche under these conditions is due to genetical influence. It is thought that mother and father exert an equal influence on tempo of growth.

There are number of early studies of dental development that show calcification and dental emergence were highly correlated within MZ twins than DZ twin pairs, thus suggesting a heritability of 0.85-0.90. The general pattern of skeletal maturation (i.e. the tendency to be an early or late maturing individual) also suggests that the tempo of development is highly heritable with sib-sib correlations of 0.45. The process of maturation is commonly believed to be controlled, at least partially by genes independent from those controlling final size. Studies have shown that siblings may reach identical adult height even though they differed in the timings of maturational events.

Differences between populations are also due to differences in their gene pools, in their environments and in the interaction. Studies have shown that Afro-American children growing up under favourable conditions are a little taller and heavier than Europeans and Euro-Americans living in the same cities. This is partly or wholly because they are a little more advanced in maturity. Asiatics, on the other hand, under equally favourable circumstances are smaller despite being still further advanced in maturity. Even bodily proportions are different among different three major racial groups. The relatively longest legs characterise the Australians Aborigines and the Africans in Ibadan, with the former far exceeding

the latter. Londoners and Hong Kong Chinese both have relatively shorter legs than Africans, but the Chinese pattern of growth seems to be different from the European. Initially Chinese have relatively longer legs than the Londoners, but during growth they consistently gain less in leg length per unit sitting height. Asiatics have their characteristically short legs from about mid-childhood onwards, to a degree which rapidly increases until growth ends than the Londoners.

Racial differences in shape can also be seen in the relation of biacromial to biiliac width. Afro-American boys and girls in Washington have considerably narrower hips relative to shoulders than either Londoners or Hong Kong Chinese. Chinese are not greatly different from Londoners in this respect except that adolescent girls appear to gain more in hips. There are differences in body composition also, Africans having more muscle and heavier bones per unit weight at least in males, together with less fat in the limbs in proportion to fat on the trunk (Eveleth and Tanner, 1976). The African new born is ahead of the European in skeletal maturity and motor development. He maintains this advance for some 2 or 3 years in most areas in Africa after which nutritional disadvantage interrupts. In America and Europe the African stays in advance in bone age and also in dental maturity. The mean age at menarche for African descended was 12.5 years and 12.8 years for European descended. Well off Asiatic groups have as fast a tempo as Africans, in later childhood if not in earlier years. Mean age at menarche in Hong Kong girls from affluent families was found to be 12.5 years.

Inherited differences of body build may arise by either genetic drift or natural selection. If a small population colonizes a remote habitat, this group may by chance have an unusual frequency of genes favouring a particular body form, and because of limited opportunities for mating, these characteristics will persist in subsequent generations. Moreover, there will be fewer heterozygotes than in larger communities, and some gene combinations with a low initial frequency may disappear from the population by mere chance. However, if a particular body form has favoured survival, there will also be selective pressure increasing the frequency of any related gene combinations with in the population. Further, in an isolated population the apparent advantages of a particular body form might be exaggerated by emergence of unusual pattern of diet and lifestyle within the community.

2.7 BIOCHEMICAL METHODS

Growth trends and nutritional status of a child/community can be evaluated by means of field surveys, with the help of clinical examination, anthropometric measurements, biochemical tests and dietary intake along with information on socio-economic, demographic and ecological variables. Nutritional anthropometry is concerned with the measurement of the physical dimensions and the gross composition of human body at different age levels. However, it does not give specific information about the nutrients. For that information a variety of biochemical tests are useful. Although biochemical estimations of nutritional significance can be carried out on a variety of body tissues including liver, muscle and bone. In practice in field surveys, tests are confined to two fairly easily obtainable body fluids, blood and urine. Laboratory tests can be altered by medications, hydration status, disease status or other metabolic process such as stress. Biochemical tests can be employed to test the relative adequacy

of dietary intake, metabolic changes due to tissue malnutrition and depletion of body stores of proteins. Alterations in amino acid metabolism have been demonstrated in Kwashiorkor caused by enzyme defects and inadequacy of plasma proteins especially albumin.

Plasma from blood sample is required for examinations for albumin, vitamin A, carotene, ascorbic acid and alkaline phosphatase. Fresh whole blood is used for the determination of haemoglobin. Anaemia can occur from iron deficiency of various nutrients. The principal ones are iron, folic acid and vitamin B_{12}. Iron deficiency may exist in the body as a result of inadequate dietary intake, poor absorption or a combination of both. This is especially likely to happen in early childhood when the iron needs are high and the food eaten tends to be poor source of iron. We can detect anaemia by testing haemoglobin levels of children/ population and can compare these with standards of haemoglobin suitable for the particular age groups. Haemoglobin levels are independent of climate, but attention may be paid to the effects of high altitude as well as other causes of anaemia, such as malaria, sickle cell diseases and folic acid deficiency. Urine samples are used for detection of urea, thiamine, urinary iodine, and riboflavin etc. However, when used as a measure of body muscle mass for creatinine estimation, urine has to be collected over a time period- minimally three hours and preferably twenty four hours. Creatinine, a product of muscle metabolism is excreted into the urine and can provide accurate estimate of muscle mass utilisation. This measurement can be affected greatly by renal function.

Biochemical investigation may give information on the nutrient supply to the body as reflected by levels in a particular tissue, most often the serum, e.g., ascorbic acid. However, the concentration of an essential nutrient in a body fluid may be reduced as a result of dietary deficiency, poor absorption, impaired transport (as can result from plasma protein in protein calorie malnutrition), abnormal utilisation or a combination of these. While the measurement of nutrient concentration is helpful in suggesting the possibility of malnutrition, it does not indicate the presence or define the degree of nutritional disease.

Some biochemical test can be undertaken that reveal metabolic changes resulting from tissue malnutrition due to inadequate levels of essential nutrients, often of long duration. The detection of such metabolic changes aids in the assessment of nutritional status and in many instances indicates a state of deficiency with greater certainty than does a mere lowering of tissue concentration of essential nutrients. These changes sometimes precede the appearance of clinical manifestation of malnutrition. A decreased availability of iodine to the thyroid may be the result of its inadequate intake and can be detected as thyroid enlargement especially in school children. The nutritional significance of the results of biochemical tests in a community has to be correlated with all the other findings i.e. clinical, anthropometric, dietary and ecological.

2.8 ENVIRONMENTAL FACTORS

Growth is a product of continuous and complex interaction of heredity and environment. A considerable proportion of the mean differences in body size between the populations being observed are due to the effects of environmental conditions. Some of the differences between individuals within populations are also due to differences in environment. In the better-off populations of

industrialised countries these differences are relatively small, while in developing countries the gap between well-off and poor is greater. A child may receive numerous insults (diet low in calories or proteins) during growth and yet survive, but bodily adaptations for survival are made which may result in smaller body size. When environmental conditions improve the size of child also improves. Many environmental factors influence rate of growth but most of them hinge upon the level of nutrition besides infections from disease, socio-economic level and family size, urbanization, climate and seasonal effects and psychosocial stress.

Enumerate the role of various environmental factors in regulating human growth.

2.9 NUTRITIONAL FACTORS

Adequate nutrition is essential for normal growth at all ages. Malnutrition delays growth. The period when the child is most at risk from the combination of malnutrition and infection is from birth to 5 years. Many populations in developing countries have mean birth weights at the same level as those in developed countries but it is only after 6 months that the weight gains diminish as a result of the interaction of undernutrition and infection. The slowing down in weight growth in some areas coincides with age of weaning and the substitution of high starch, low protein foods. It is also the age at which the mother's lactating ability declines so that satisfactory growth cannot be achieved by breast milk alone.

Researchers have discussed the question of whether under nutrition in the first or second year of life necessarily leads to an adult deficit on body size. It has been seen that children with severe protein-calorie malnutrition in early infancy due to malformations or malfunction of the gut make a complete recovery in height after surgical correction when brought in well off homes in a developed country.

Evidently much depends on the circumstances when the severe episode of malnutrition is over. Children less than five years admitted to hospital in tropical countries with severe protein-calorie malnutrition (Kwashiorkor or Marasmus) were followed after discharge. In most of such children complete equality of height and weight with sibling controls was attained before puberty. In other long term deficits were reported and their growth was not equal to their siblings but was more close to the general population, a less appropriate control. Long periods of under nutrition, often combined with chronic infections; certainly have lasting effects on body size.

Body shape is made more resistant to nutritional stress or even disease than is body size. Malnutrition in man does not alter significantly the shape of the body; a malnourished European child by no means acquires the short legs of the Asiatic. These days along with malnutrition, overweight is also causing an increasing problem of obesity not only in developed countries but also in developing countries. Recent evidence suggests that overfeeding in first year or 18 months after birth may have much to do with the tendency to become obese later.

During the period of 5 years to adolescence the child is growing less rapidly and presumably because of this few populations show height and weight means decreasing further. A second period when the child may be especially sensitive

to influence of under nutrition is at adolescence. The calorie requirement increases at this time in level with the increased growth of the adolescent spurt. Lack of sufficient calories may result either in a smaller spurt or a delay in the age of the spurt. The latter reflects chiefly on accumulating deficit in the years preceding adolescence. Tempo seems usually to be first thing affected. In data from well off families in all populations, age at menarche is earlier than children from underprivileged section. Girls from larger families also had consistently late maturation than those from smaller ones. Poor nutrition during childhood slows up skeletal maturation and also affects width of cortical bone. Thus, level of nutrition of children in a population has to be studied in relation to their ecological aspects and most importantly its implications on human growth and maturation.

2.10 EFFECT OF DISEASE

In well-nourished children the effects on growth of minor diseases are minimal. An ill child is a poorly growing child, although the extent of slowing down depends on number of factors. Poorly nourished children are more susceptible to and more severely affected by infection than well-nourished children. Infection in turn lowers the nutritional intake of the child, who in turn becomes prone to repeated infections. Measles and whooping cough are severe diseases in developing countries where chronic undernutrition may affect two third of the population. In malnourished children suffering from measles the mortality is many times higher than in well nourished children.

In developed countries with good nutrition measles is no longer considered a severe disease and when it occurs it is more frequently in older children from 3 to 5 years rather than under two years. But in poorly nourished children the weight loss associated with measles may take from 4 weeks to 3 months to regain. Longitudinal studies have been carried out by researchers in Guatemala and Jamaica to examine the effect of infectious disease on growth in the first three years. Short term weight loss was frequently seen. In Jamaica the long term picture was one of catch-up growth causing complete restoration of growth status, but in Guatemala it was not completely restored. Therefore, it is very important to protect children from catching infections by taking preventive measures for their overall better growth.

2.11 SOCIO-ECONOMIC STATUS AND FAMILY SIZE

Children from families belonging to the high or middle socio-economic groups in any country are on average larger in body size than their counterparts in the lower economic groups. High income and high educational level imply not only better nutrition but often also better child care and better use of medical and social services. Differences between socio-economic classes in height and weight are found in developed as well as in developing countries. In the British National Child Development Survey, a nationwide sample of children consisting of all those born in one week of March 1958, an overall difference of 3.3 cm was reported between seven years olds from the professional and managerial classes and those from the unskilled, manual working class. Similarly in the U.S. national sample of children measured by the National Centre for Health Statistics, children aged 6 to 11 were some 3 cm taller in the rich families than in the poor ones. At

the University of Paris, the tallest students were children of parents in intellectual professions while the shortest and heaviest from worker and peasant families. Reports of socio-economic class differences in growth from developing countries including India show the very great differences in height and weight of 5 years olds in upper and lower social classes that exist in many cities.

These differences are compounded by differences in height and tempo according to number of sibs in the family. First born children are somewhat taller than later born children with the same number of sibs, since they have had a period of being an only child. The more mouths to feed, it seems or simply more children grow. This difference is solely of tempo, because children do not differ systematically according to birth order when they are fully grown. All the differences in social class may not be of direct environmental origin, however classes are to some extent endogamous, and movement from one social class to another in some countries is linked with size as well as ability.

In Belgium, young men who were moving up the scale occupationally (i.e. entering a more prestigious and better rewarded occupation than their fathers) were larger, healthier and scored higher on intelligence test than those who stayed in the same or equivalent occupation. The downwardly mobile showed approximately the opposite picture.

2.12 URBANISATION

Children in urban areas are usually larger than children in the surrounding rural areas. Indeed the tendency towards greater size and more rapid maturation in Europe in the last hundred years has been held to be a consequence of urbanization. By urbanization we do not mean simply a high population density, other features such as a regular supply of goods, health and sanitation services, large medical institutions, educational, recreational and welfare facilities must be present. A European or North American city is considerably different from urbanized area in Africa or even a city in India or Japan.

Data from European countries on height and weight from Finland, Greece and Rumania also shows that children in the cities are larger than those in rural areas, but the amount by which urban children were taller and heavier varied. Eight year old boys in Helsinki, for example, were 2.4 cm taller and 1.6 Kg heavier than rural Finnish boys, while in Greece the urban-rural differences were twice as great. During puberty the differences became greater, presumably because of the earlier appearance of the adolescent spurt in city children. While part of urban-rural differences results from earlier maturation. In developing countries also the same trend is being witnessed, urban children being taller and getting matured earlier than the rural children. Better off children, that is children who live in parts of towns that are nearer to urban areas are considerably taller and heavier than the rural children.

In every urban-rural comparison so far reported urban girls have an earlier menarche than rural girls. As with growth in body size, age at menarche is closely related to the health and nutritional level of an individual or a population. In a study from Bombay even urban slum children have been reported larger than children in the corresponding rural areas where even the poor were said to have received more food in the first two years after birth than children in rural areas.

Many studies conducted in India on growth of rural-urban children also show better overall growth and earlier maturity among urban children than their rural counterparts.

2.13 SEASONAL AND CLIMATIC VARIATION

A seasonal variation in rate of height growth has long been recognised in the temperate zones. Children tend to grow faster in height in the spring and summer and faster in weight in the autumn and winter. Marshall (1971) in a longitudinal study found that in children 7 to 10 years of age maximum height velocities were reached in 3 month, periods ending between March and July, and minimum height velocities in the periods ending between September and February. During the 3 months of fastest growth, a child on average grew three times as much as during the 3 months of slowest growth. The cause of these differences is unknown. Totally blind children showed similar variations in rate to sighted children but failed to synchronize them with season of the year. Length of daylight seems to play only a minor part.

Seasonal variation in height and weight growth is governed by the rainy and dry periods in tropical areas. The rainy season is marked with food supply running low and the frequency of infections is highest. In Gambia, children under 3 years had good weight gains during the dry season but experienced low gains and even weight loss during the wet period. In Tanzania, both African and European school children displayed seasonal changes in height and weight gain, however the differences in weight were not constant in both the groups. Change of season has an impact on diet of an African child whereas that of the Europeans remains relatively constant. Thus, it can be concluded that different factors may be responsible for seasonal variations in the two areas.

Moreover, the effect of altitude on growth has also been studied. In general, people living at high altitude are smaller than those living at sea level or plains. The principal environmental factor affecting human physiology at altitude 3000 meters is the low atmospheric pressure which reduces the partial pressure of oxygen in the inspired air. It results in hypoxia, a condition in which haemoglobin carries less oxygen than at sea level and oxygen tension in the plasma is reduced. Other factors which affect growth of man at higher altitude are cold, lower air density and nutrition. As a result of adaptation to high altitude, the period of growth is slow and prolonged; Individuals have larger chest circumference, higher average lung size and higher haemoglobin concentrations as compared to individuals living in plains and at sea level.

2.14 PSYCHOSOCIAL STRESS

Psychological stress has been found to be contributing towards relative failure to grow in some children. It does this by affecting the secretion of growth hormone. As soon as stress is removed secretion of growth hormone starts again, and in clinical cases, a catch–up occurs. This is indistinguishable from the catch-up as a result of administering of human growth hormone to a child who is permanently deficient in growth hormone for structural reasons.

Studies have shown that the majority of children suffering from fairly severe stress continue to grow when given sufficient food, even in astonishingly stressful

circumstances. Let us narrate the famous experiment of Widdowson of Cambridge University who provided some proof that the presence of a sadistic school teacher was a reason for affected growth in children in orphanage by slowing it down, even though a simultaneous increase in the amount of food eaten is there. Some earlier studies have shown that certain boarding-school boys grew more slowly in term-time than they did in holidays at home. Tanner and Whitehouse confirmed this finding. On the other hand it is quite possible that a boarding school may provide the friendly atmosphere required for catch-up to a child whose growth has been stunted by an adverse home. Thus, psychosocial stress can contribute towards slowing down the growth of a child. Therefore, it is important to have a congenial atmosphere at home as well as in schools and working places for the normal growth of an individual.

2.15 SUMMARY

Growth is the result of three forces: the genetic program, action of environmental factors and the interaction between the two. Potentialities of growth are inherent at the time of the conception and are determined by genes but without a favourable environment normal growth cannot occur. Different sets of hormones influence growth at different ages. There are many environmental factors that influence growth; an adequate supply of proper nutrients being one of the greatest importances.

In this chapter we have tried to explain different methods of studying growth keeping in mind the nature of the study and discussed their advantages and disadvantages. This information will help you in choosing the most appropriate method to be employed while undertaking growth studies. Short-term changes in body size occurring between consecutive generations are called secular trends. This word has been taken from a Latin word "Saeculum" meaning "for a generation". You may now be in a position to define and describe secular trends as observed in different populations with the help of examples given in the lesson. The role and importance of genetic factors has been explained in relation to body size, body shape and tempo of growth with the help of family and population studies. The environmental factors (nutrition, disease, socio-economic status, family size urbanisation, seasonal and climatic variations and psychosocial stress) which play an important role by acting on the genetic potential have been explained in detail and it will be easier for you to understand the cumulative effect of all these factors on human growth and development. The concept of catch up growth i.e. accelerated velocity during recovery is a very fascinating phenomenon and perhaps now you will be able to understand in your day to day life while observing it in the family and among friends. Similarly, you can understand the differential growth and maturity status of different body segments. Anaemia and malnutrition are the most prevalent disorders prevalent in developing countries. Biochemical methods can be used to detect anaemia, malnutrition, hormonal levels and various other deficiencies as has been described in the chapter. Thus, for anthropologists, growth data as an indicator of public health and nutritional status of children assume ever increasing importance because growth monitoring in children can serve as a powerful tool for appropriate action to promote improved health and nutritional status.

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Sample Questions

1) Give a brief account of various methods of studying human growth giving their advantages and disadvantages.

2) What do you understand by catch-up growth? Explain it with the help of examples.

3) Discuss the role of biochemical methods in evaluating human growth.

4) How do genetic factors affect human growth and development? Explain with the help of examples from families and populations.

5) What do you know about environmental influences on human growth? Explain the role of nutrition, socio-economic status and psychosocial factors in detail.

UNIT 3 HUMAN CONSTITUTION AND PHYSIQUE

Contents

Learning Objectives

After going through this unit, you should be able to understand the:

- concept of somatotype;
- features of various somatotypes; and
- methods for assessing somatotypes which deal with variability in human physique.

3.1 INTRODUCTION

Observation of variation in human body build and interest in relation of such variation to temperament and disease susceptibility are as old as science. Earlier studies on review of the history of human classification defined constitution as the sum total of the morphological, physiological and psychological characters of an individual, in large part determined by heredity but influenced in varying degrees by environmental factors or simply the total biological make-up of an individual. Physique which refers to individual body form is probably the single aspect of constitution.

> Somatotype refers to a quantified expression and description of the present morphological conformation or physique of a person and the process of appraising and defining it is known as somatotyping.

3.2 CONCEPT OF SOMATOTYPE

History of somatotyping can be traced back to the fifth century BC, when Hippocrates offered two fold classification of physique:

Habitus phthisicus, long and thin individuals considered susceptible to tuberculosis.

Habitus apoplecticus, short and thick build individuals susceptible to vascular disease leading to apoplexy.

Ever since that time, there have been several attempts to describe and classify the humans. All the efforts ultimately lead to a common conclusion of describing human body forms in two or three major types: lateral (round), muscular and linear.

The study of physique has pivotal role to play in understanding growth, maturation and performance. During the growth phase, it is clear that in childhood and adolescent phase the genesis of the variation which is observed in adulthood takes place. Somatotyping is an outstanding tool to explore the spatial temporal variations and observe the changes occurring as a result of physical exercise on human physique. Moreover it combines an appraisal of relative adiposity, musculoskeletal robustness and linearity into a three scale rating. The development of anthropometry added new dimensions to the study of morphology. Somatotype distribution in various ethnic groups are markedly more restricted and dominated by extreme somatotype than the nationality samples. Studies reveal that Eskimos (Alaska) are primarily endo-mesomorphic, Manus (Papua New-Guinea) and Caingang (Brazil) presents conspicuously mesomorphic somatotypes with extremes towards mesomorphy. Strikingly, extreme ectomorphic somatotype is shown by Nilotes of the Nile valley in Africa and many population groups living in hot environments of the tropics.

3.3 METHODS IN THE ASSESSMENT OF PHYSIQUE

As mentioned, there are different conventions which have described human forms and nearly all categorize physiques into three categories corresponding to lateral, musculature and linear types.

3.3.1 Viola's Method (1921)

Viola, an Italian physician proposed a classification of biotype (physique) based on a comprehensive system of anthropometric measurements. For general purposes, he took ten measurements:

a) Sternum length

b) Upper abdominal height

c) Lower abdominal height

d) Length of the arm

e) Length of the leg

f) Transverse thoracic diameter

g) Antero-posterior thoracic diameter

h) Transvere hypochondric diameter

i) Antero- posterior hypochondric diameter

j) Bi-iliac or transverse pelvic diameter

Three compound measurements namely stature, trunk height and total abdominal height were also considered. By manipulating these measurements he derived a measure of trunk volume and four morphological indices namely thoracic index, upper abdominal index, lower abdominal index and total abdominal index. He differentiated three morphological types:

1) **Longytype**: The longytype had long limbs relative to their trunk volume, large thorax relative to their abdomen, a large transverse diameter relative to anterior posterior diameter.

2) **Brachitype**: The brachitype was characterised by massiveness and robustness of body, the reverse of longytype. They had short limb relative to trunk, short transverse diameter relative to the antero-posterior diameter, short thorax relative to the abdomen.

3) **Normatype**: The normatypes were in between longitype and brachytype characterised by normally proportional limbs versus trunk, thorax versus abdomen, transverse versus antero-posterior widths.

4) **Mixed**: Mixed type shows disproportion in human body. It lacks uniformity in the physique.

   The four indices failed to agree amongst themselves, one placing the individual in one category and another else where. It is obvious that Viola's biotypology based on anthropometric measurements is morphological in orientation.

3.3.2 Kretschmer's Method

Kretschmer was a German psychiatrist. His system of classification relied entirely on anthroposcopic inspection. He illustrated four physical and psychic types derived from his clinical observations and minimum measurements:

1) Pyknic: The pyknic was broad, round and fat, sturdy and stocky.
2) Athletic: The athletic was heavily muscled with large thorax and shoulders and narrow hips.
3) Asthenic: The asthenic was long, thin and linear.
4) Dysplastic : It denoted the incompatible mixture of different types in different parts of the body.

Later he substituted the word leptosome for asthenic.

Criticism

This system is now entirely outdated.

a) It supposed that it was possible to classify people into separate discrete types. This assumption was widespread up to about the 1930's. The later practitioners had to admit that most people fell in between the established and obviously fairly extreme types.

b) It had also been criticized of limited sampling, scanty measurements, lack of indices, subjective estimates, and failure to classify data according to age, sex and social status.

3.3.3 Sheldon's Method

William Herbert Sheldon (1898-1977) was an American psychologist and physician. He introduced the concept and word 'somatotype' in 'The Varieties of Human Physique' (1940). He defined somatotype as 'quantification of three primary components determining the morphological structure of an individual expressed as a series of three numerals, the first referring to endomorphy, the second to mesomorphy, and the third to ectomorphy'. The conceptual approach is based on the premise that continuous variation occurs in the distribution of physique and thus the variation is related to differential contributions of three specific components, named on the basis of three embryonic germ layers:

Source: www.somatotype.org

- **Endomorphy**: It is characterised by the predominance of the digestive organs and softness and roundness of contours throughout the body. In other words, with increased fat storage, a wide waist and a large bone structure. Endomorphs are referred to as fat.

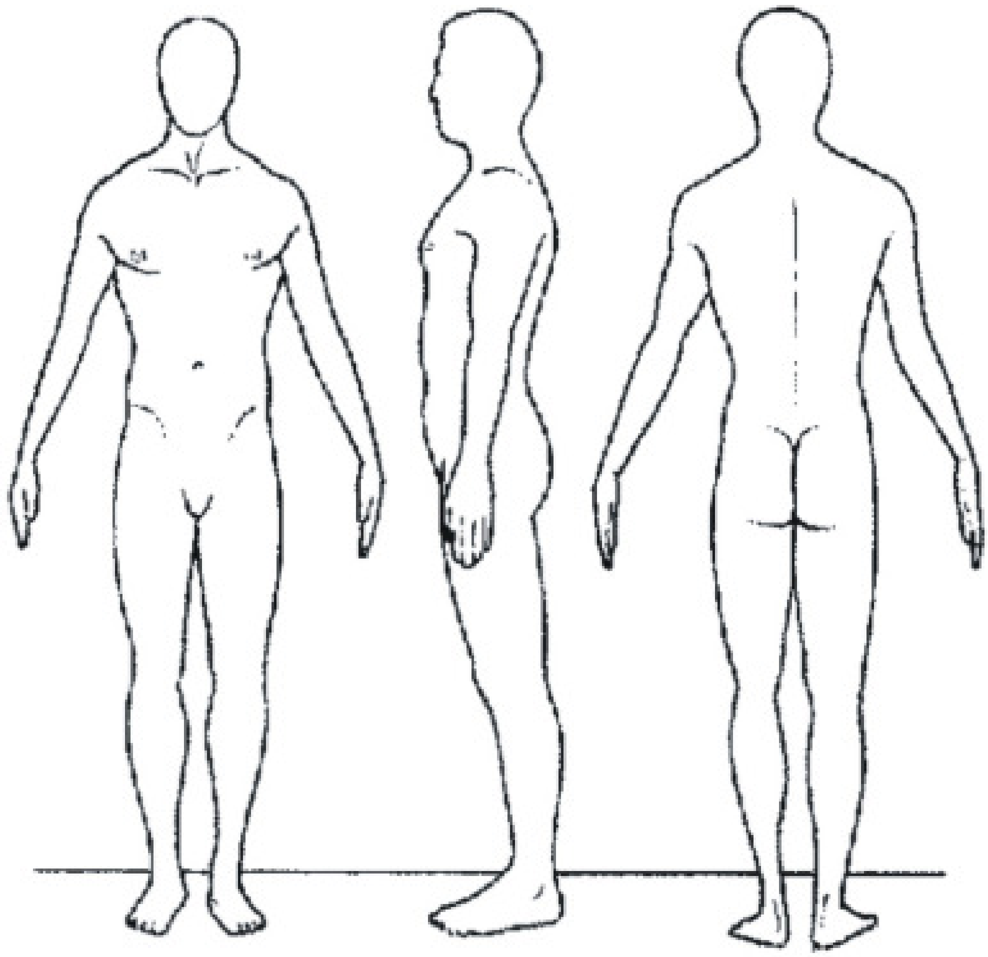
- **Mesomorphy**: It is characterised by the predominance of muscle and bone, skin is made thick by heavy connective tissue. The physique is normally heavy, hard and rectangular in outline. In other words, with medium bones and solid torso, low fat levels, wide shoulders with a narrow waist. Mesomorphs are referred to as muscular.

- **Ectomorphy**: It is characterised by linearity and fragility of build; with limited muscular development and predominance of surface area over body mass in other words, with long and thin muscles or limbs or low fat storage. Ectomorphs are referred to as slim.

The contribution of the three components defines an individual's somatotype.

Method

Sheldon's method of estimating somatotype utilises height and weight and three standardised photograph of front, side and rear views of the nude subjects i.e., 4000 college men standing before a calibrated grid. He summarized his photoscopic (he called it anthroposcopic) somatotype method as follows:



Front view **Rear view** **Back view**

Source: www.Sports.jrank.com

a) Calculation of height/$\sqrt[3]{weight}$ ratio (HWR) or reciprocal ponderal index

b) Calculation of ratios of 17 transverse measurements/diameters (taken from photographic negatives) to stature.

  1) Four on head and neck

  2) Three on the thoracic trunk

  3) Three on the arms

  4) Three on the abdominal trunk

  5) Four on the legs

c) Inspection of the somatotype photograph, referring to a table of known somatotypes distributed against the criterion of HWR, comparing the photograph with a file of correctly somatotyped photographs, and recording the estimated somatotype.

d) Comparison of the 17 transverse measurements ratios with the range of scores for each ratio, to give final score

Each component of physique is assessed individually. Rating are based on a 7-point scale, with 1 representing the least expression, 4 representing moderate expression and 7 representing the fullest expression of that particular component

being assessed. The rating of each component determines the somatotype which is expressed by three numerals to sum of no less than 9 and no more than 12. The first number refers to endomorphy, second to mesomorphy and third to ectomorphy. Sheldon identified 76 different somatotype and most common are 3-4-4, 4-3-3 and 3-5-2.

The extreme somatotypes are:

1) **Endomorphy**

   a) Various parts of the body are soft and round

   b) Head is round

   c) Abdomen is flat

   d) Arms and legs are weak and fatty

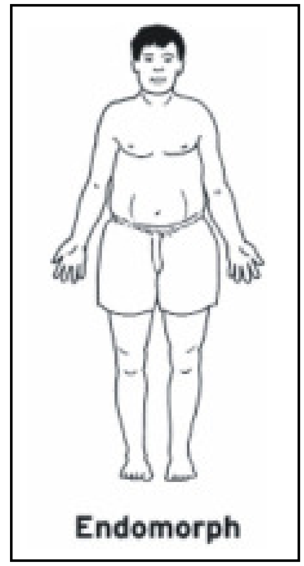
   e) Upper arms and thighs are fatty

   f) Wrist and ankles are splendidly built

   g) Less linearity and less muscularity

   h) More fat deposition

   i) Somatotype rating is 7-1-1



2) **Mesomorphy**

   a) Bony and Muscular

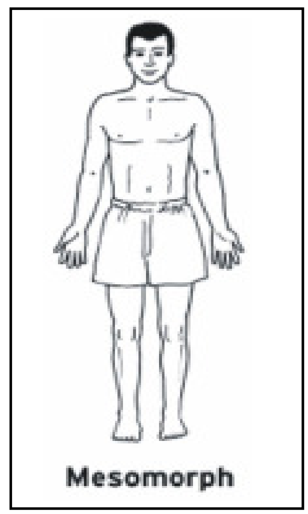
   b) Heavy, coarse physique with rectangular contour

   c) Their head is massive and cubical

   d) Shoulder and chest broad

   e) Less fat and less linearity

   f) Somatotype rating is 1-7-1



3) **Ectomorphy**

   a) Typical characteristic is linearity

   b) Face is thin

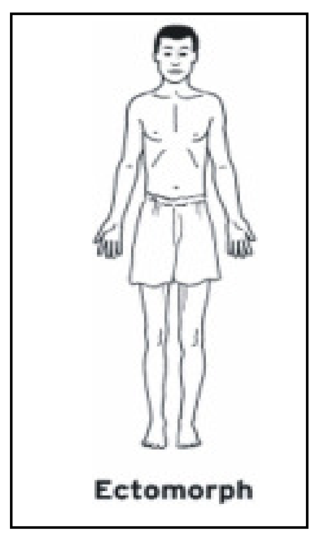
   c) Forehead is high

   d) Chin is receding

   e) Chest and abdomen is thin and narrow

   f) Less fat and less muscularity

   g) Somatotype rating is 1-1-7



Source: www.ratemyarms.com

Criticism

- ❖ The somatotype changes: Sheldon stated that the somatotype is a trajectory along which an individual under average nutritional condition and absence of major illness is destined to travel. He used the word 'morphophenotype' to refer to the present physique and 'morphogenetic' to refer to genetically determined physique. He maintained that somatotype do not change throughout because it does not change significantly for any measurements except where the fat is deposited.

- ❖ Somatotype is not objective: Sheldon claimed that making measurements on photographs has raised the subjective technique to strictly scientific and objective level. He developed his own anthropometric method which depends upon soft part outline in the photograph more than osseous landmark.

- ❖ There are two, not three primary components, for endomorphy and ectomorphy are essentially the inverse of each other.

- ❖ Somatotyping omits the factor of size: In original method somatotype measured only body shape independent of body size.

- ❖ The method of somatotyping was developed on adult males. Criteria for defining somatotype components in children or females were not published.

- ❖ He used arbitrary scale that permitted no rating more than 7 or less than 1 in any component and their sum is limited by the numbers 9 and12.

Sheldon's objective method

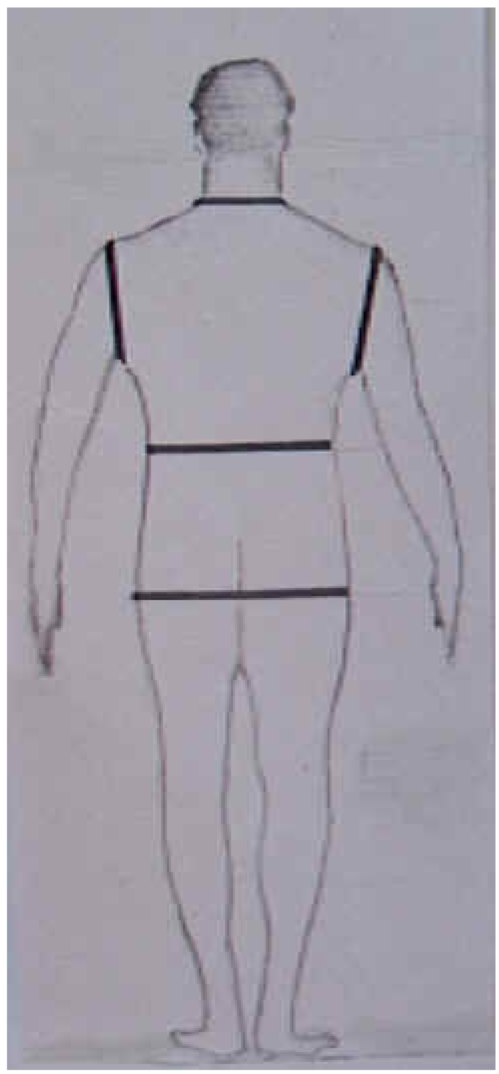
Source: www.innerexnloration.com

To meet these criticisms Sheldon described a 'new' Trunk Index method derived from the ratio of the areas of the thoracic and abdominal trunk measured on somatotype photograph.

- ❖ This index is assumed to be constant throughout life. It is possible that in the succession of the life phases the area ratio of thoracic trunk to abdominal

trunk remains constant, that the two area increase and decrease in the size in relation to one another.

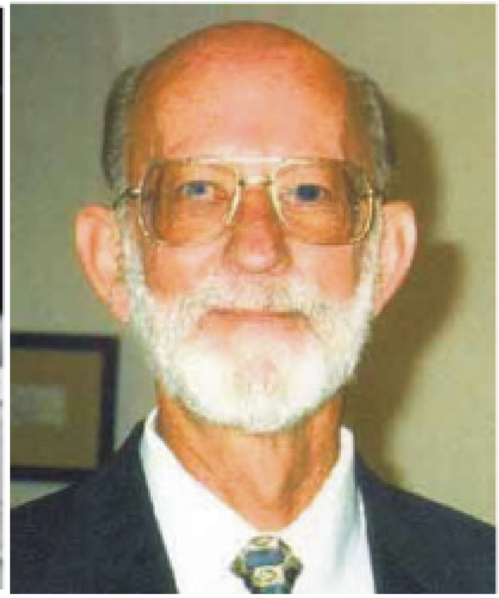
- ❖ He asserted that the new system provided a measure of massiveness (HWR), a separator for the kinds of mass into endomorphy and mesomorphy (The trunk index) and finally a measure of degree of stretching out into space (height). When the other two parameters are known, this is precisely what ectomorphy is.
- ❖ In this new method height was used as a measure of size, and substituted for ectomorphy.
- ❖ As a result of these changes, the sum of the somatotype components no longer need be limited to sum of 9 to 12 but now can extend to sums of 7 to 15.
- ❖ The original matrix of 76 somatotypes expanded to 88.The trunk index matrix gives 267.



Areas to measure when determining the trunk index

Source: www.innerexploration.com

3.3.4 Heath-Carter Method



Heath
Physical anthropologist

J.E. Lindsay Carter
Professor, San Diego State University

Source: www.somatotype.org

Heath (1963) described certain limitations in Sheldon's method and suggested the following modifications to overcome them:

- Opening the component rating scales to accommodate a broader range of variation by replacing the arbitrary 7-point scale with a rating scale of equal appearing intervals. Beginning theoretically with zero (in practical beginning with one half) and having no arbitrary end point.
- Eliminated the unjustified restrictions of sums of components to between 9 to 12.
- Construct a table that preserves a logical linear relationship between somatotype rating and HWRs.
- Adopt a single table of HWRs (Height-Weight Ratios) and somatotype suitable for both sexes at all ages.

Heath and Carter combined both photoscopic and anthropometric procedures to estimate somatotype. Somatotype is defined as representing the individual's "present morphological conformation; expressed in a three numeral rating of primary components of physique that identify individual features of morphology and body composition". In practice, the Heath-Carter method of somatotyping is primarily in its anthropometric form. Anthropometry is more objective and obtaining standardised somatotype photographs is difficult and costly.

The somatotype components and the dimensions used in the Heath-Carter anthropometric protocol to derive each component are as follows:

1) **Endomorphy** (1/2-16th scale): The first component, endomorphy, is described from the sum of three skinfolds namely the triceps, subscapular, and suprailiac. It refers to relative fatness of a physique.

2) **Mesomorphy** (up to 17th scale): The second component, mesomorphy, refers to relative musculoskeletal development adjusted for stature. It is described as expressing fat-free mass relative to stature. Mesomorphy is derived from biepicondylar breadths of the humerus and femur, flexed-arm circumference corrected for the thickness of triceps skinfold and calf circumference corrected for the thickness of the medial calf skinfold corrected of the thickness of medial calf skinfold. Correcting the circumferences is simply a matter of subtracting the skinfold thickness from circumference. These four measurements are then adjusted for stature.

3) **Ectomorphy** (up to 9th scale): The third component, ectomorphy, is the relative linearity of build. It is based on the reciprocal ponderal index.

There are three methods for obtaining a Heath- Carter somatotype. They are as follows:

1) The photoscopic somatotype

2) The anthropometric somatotype

3) The anthropometric plus photoscopic somatotype

The anthropometric somatotype can be calculated from the 10 anthropometric dimensions viz. height, weight and skinfolds (triceps, subscapular, supraspinale, and medial calf), two girths (flexed upper arm and calf) and biepicondylar breadths (humerus and femur).The algorithms for estimating a somatotype with the Heath-Carter anthropometric protocol are as follows:

a) Endomorphy = $-0.7182+0.1451(X)-0.00068(X^2)+0.0000014(X^3)$

Where, $X = \sum 3$ skinfolds viz. triceps, subscapular and supraspinale skinfolds; and adjustment for stature is made where X is multiplied by 170.18/height (cm).

b) Mesomorphy = $(0.858 \times$ humerus breadth $+ 0.601 \times$ femur breadth $+ 0.188 \times$ corrected arm girth $+0.161 \times$ corrected calf girth$)-(0.131\times$ stature$)+4.50$

Where, corrected arm girth = Arm girth – triceps skinfold in cm and corrected calf girth = calf girth – medial calf skinfold in cm.

c) Ectomorphy = $0.732\times$ HWR -28.58 (If HWR>40.75)

= HWR $\times$ 0.463-17.63 (If HWR>38.25 but <40.75)

= 0.1 (If HWR=39.25)

Where HWR = stature/ $\sqrt[3]{\text{weight (kg)}}$.

The advantages of anthropometric somatotype are it provides

1) an objective method of somatotyping.

2) the best estimate of a criterion somatotype in the absence of a photograph.

Limitations

1) The first component endomorphy represents the fat free mass and second mesomorphy components reflect the fat mass. The body components present specific body composition concepts, which means it partitions body weight

into its lean and fat components. Sheldon's original somatotype concept however refers only to body shape and not to body composition. Although, both methods use the term somatotype, but it has different meaning in each.

2) Endomorphy has been found to correlate moderately well in terms of body fat, though fat free mass correlates rather poorly with mesomorphy. Moreover, the association of mesomorphy and limb muscularity is generally low in athletes based on dual energy X-ray absorbtiometry. This needs the validation of relationship implied in the concepts used to define physique.

3) The variation in the reproducibility of somatotype components in the Heath-Carter anthropometric protocol is guided by intra-observer and inter-observer measurement. An error of 0.5 somatotype units is there when the body dimensions are measured by experienced technicians.

4) The validity of this method for children 6 years and below has not been established. This could be one of the factors attributed to studies projecting high ratings of mesomorphy in young children

3.4 SUMMARY

Human variability in body size, shape, and proportions due to age, sex, nutrition, physical activity and environment are topics that are of considerable interest to physical anthropologists and human biologists for a long time. Somatotypes change due to growth or reduction of body constitution at differential rate. Somatotyping, an index of physique/human variability has sought to identify physical adaptations to environmental conditions such as heat, humidity, and altitude. Furthermore, discerning the associations between fitness and physical performance, and different somatotypes has been an important research task. Anthropometric approaches are, of most part non-invasive methods that assess the size, shape or body composition of an individual. Somatometry is considered as one of the best tool for growth studies as these values are closely related to nutrition, genetic makeup, environment, social and cultural condition, lifestyle and functional status. Assessment of physique derived from different methods viz Viola's Method, Kretschmer's Method, Sheldon's Method and Heath - Carter Method incorporates the terms endomorphy, mesomorphy and ectomorphy. Somatotyping recognise continuous variation in the distribution of the components of the physique. Finally, somatotyping is considered to be reasonably good method for quantification of current shape and composition of the human body and has been subject to continuous improvement in respect of its methodological issues.

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Sample Questions

1) What do you understand by the term "physique"? Give an account on different methods of classifying human physique.

2) Critically examine the various methods of studying human physique?

3) Briefly describe Heath-Carter method of assessing human physique and how does it differ from Sheldon's method?

4) What is somatotyping? Explain various methods of assessing somatotype and give its significance.

5) What are different classification of constitutional types and body physique given by different scholars?

UNIT 4 REPRODUCTIVE BIOLOGY

Contents

Learning Objectives

After going through this unit, you should be able to:

- understand aspects of the reproductive physiology of male and female;
- learn the biological aspects of human fertility;
- highlight the differences between menarche and menopause; and
- indicate other biological issues related to fertility.

4.1 INTRODUCTION

In this unit we are going to understand about reproductive biology of males and females, the biological factors related to human fertility and about menarche and menopause. We will also study other bio events related to human fertility.

Now let us try to understand about the phenomenon of reproduction among human beings. Reproduction is one of the essential characteristics of life. It is illustrated in its primitive form by the action of single –celled amoeba in dividing into two. Most of the cells of the human body have the same power of division by virtue of which growth and repair are possible.

Reproduction in man and other higher animals is a complex process involving the existence of two sexes, both of which play their respective roles in the formation of a new individual, i.e. offspring.

The reproductive organs of the male and female differ in anatomical structure and arrangement, each having functional specificities required for reproduction. The function of the male organs is to form spermatozoa or sperms and implant

them within the female so that they can meet the ova. The female organs are adapted to form ova or eggs which, if fertilized by spermatozoa, remain in the cavity of the uterus. Here an embryo or fetus is formed and is retained until the individual grown in the uterus is capable of a separate and independent existence.

4.2 THE REPRODUCTION SYSTEM

Evolutionary biology clearly indicates that the sexes are separate among human beings. As such the reproductive systems are separate and function independently. Both male and female reproductive systems function with the help of different hormones secreted by different glands, thereby they are responsible for different functions and carry out reproductive process in a successful manner.

4.3 REPRODUCTIVE PHYSIOLOGY OF MALE AND FEMALE

Before actually knowing about the reproductive physiology of males and females it is better to understand the different reproductive organs involved in it. In this sub unit we can discuss about the reproductive physiology of male and female briefly.

Human beings are bi-sexual organisms wherein sexes are separate and as such they have separate sex organs and these sex organs are specialised for carrying out certain functions. In both the sexes, different organs are meant for different functions in reproductive process. In subsequent sub-units we are going to discuss about the structure of male and female sex-organs, the related endocrine secretions and their functions in the process of reproduction in brief.

4.4 ORGANS OF MALE REPRODUCTIVE SYSTEM

The male reproductive system includes the primary sex organs and accessory sex organs. Primary sex organs are testes and the accessory sex organs are seminal vesicles, prostate gland, urethra and penis.

Testis

Testis is the primary male sex organ or male gonad. It corresponds with ovary in females. There are two testes (singular = testis) in almost all the species. Each testis contains about 900 coiled tubules known as seminiferous tubules. The seminiferous tubules produce sperms. The sperms enter the vas deferens, which form the epididymis. It is continued as vas deferens.

Seminal Vesicles

The seminal vesicles are accessory sex organs in males, which are situated on either side of prostate. Secretions of seminal vesicles are emptied into ampulla of vas deferens. The enlarged portion of vas deferens is called ampulla. The ampulla of the vas deferens is continued as ejaculatory duct, which passes through prostate to form internal urethra.

Prostate Gland

Prostate gland is also an accessory sex organ formed by numerous secretory glands. Secretion from prostrate glands follows the path to utriculus prostaticus and is then emptied into internal urethra.

Urethra

Urethra has two parts namely, internal urethra and external urethra. Internal urethra is the continuation of ejaculatory duct. Internal urethra passes through penis as external urethra. Urethra contains mucus glands throughout its length, which are called glands of litter. The bilateral bulbourethral glands also open into the urethra.

Penis

Penis is the male genital organ formed of three erectile tissue masses, i.e., a paired corpora cavernosa and an unpaired corpus spongiosum. The urethra passes through penis and opens to the exterior and the spongiosum surrounds the urethra and terminates distally to form glans penis.

Structure of Testis

The testes are ovoid or walnut shaped bodies having the organisation of compound tubular gland. Both the testes are located in the sac like structure called scrotum.

Functions of Testis

- The gametogenic function and
- Endocrine function

The production of gamete cells is called the gametogenic function. Spermatogenesis is the process by which spermatozoa are developed from the primitive germ cells in the testis known as spermatogonia. Spermatogenesis occurs in four stages.

1) Stage of proliferation
2) Stage of growth
3) Stage of maturation and
4) Stage of transformation

Now, we can discuss about how spermatogenesis takes place.

1) Stage of Proliferation

The spermatogonia near the basement membrane of seminiferous tubule are larger. Each one contains diploid number of chromosomes (23 pairs in human males). One member of each pair is from maternal origin and the other from paternal origin.

During the proliferative stage, the spermatogonia divide by mitosis without any change in chromosomal number. In human male, there are usually seven generations of spermatogonia. The last generation enters the stage of growth as primary spermatocyte.

2) Stage of Growth

The primary spermatocyte grows into the large cells. Apart from this, there is no other change in this stage.

3) Stage of Maturation

After reaching the full size, each primary spermatocyte quickly undergoes meiotic or maturation division, which occurs in two stages. In the first stage, two secondary spermatocytes are formed. In the second stage, each secondary spermatocyte divides into two spermatids. The significance of the two stages of maturation division is that, each spermatid receives only the haploid or half the number of chromosomes.

4) Stage of Transformation

The spermatids do not divide further but transform into spermatozoa by a process called spermatogenesis.

4.5 ORGANS OF FEMALE REPRODUCTIVE SYSTEM

Now we can try to understand about the female reproductive organs; specifically their structure and functions. The female sex organs are situated in the pelvis and for purposes of description may be divided into:

i) Internal organs: uterus, ovaries, fallopian (uterine) tubes, vagina

ii) External organs: mons veneris, labia majora and minora, clitoris, hymen

iii) Secondary organs: the breast or mamae (mammary glands).

Internal organs

In the following paragraphs you will briefly know about the female reproductive organs, their structure and functions.

The Ovary

There are two ovaries (female gonads), right and left, lying on each side of the upper pelvic cavity situated against the pelvic wall near the uterus. Each is about the size of a large almond and is attached to the posterior aspect of the broad ligament of the uterus by a fold of peritoneum. It lies immediately below the fallopian tube which forms an arch over the top of the ovary and ends just below its lateral margin.

Structure

Briefly the ovary may be described as having (i) a medulla in the centre consisting mainly of fibrous tissue or stroma, and (ii) a cortex on the surface consisting of a layer of epithelium (the germinal epithelium), a number of cystic spaces of various sizes – the Graafian follicles – which contain the ova surrounded by a little fluid, and a yellow body – the corpus luteum – formed after a Graafian follicle has ruptured and discharged its contained ova and fluid.

Functions

i) To produce ova.

ii) The Graafian follicle secretes the hormone oestrogen

iii) The corpus luteum secretes the hormone progesterone.

The Fallopian Tube

The fallopian tubes, two in number, named after the 16th century Anatomist, Fallopins, are about 10 cm (4 inch) in length and lie in the upper margin of each broad ligament of the uterus, thus being surrounded by peritoneum. The outer end of the tube is expanded and has an opening into the peritoneal cavity. This is surrounded by a number of fringes – like processes, the fimbriae, which lie close to the lateral part of the ovary. It has already been seen that the middle of the tube curves round the ovary like an arch.

Structure

The fallopian tube has a muscular wall continuous with that of the uterus. Its outer surface is covered by peritoneum, while its inner lining or mucous membrane is formed of ciliated epithelium.

Function

Its function is to collect the ova discharged from the ovary in its fimbriated end, and pass them along its interior towards the cavity of the uterus by the action of its ciliated epithelium. Fertilization of the ovum by spermatozoa usually takes place in the tube.

The uterus

The uterus (womb) is a hollow, pear-shaped organ situated in the pelvic cavity above the urinary bladder and in front of the rectum. It has thick muscular walls and a small central cavity. In the nulliparous women (those who have never borne a child) it measures about 7.5 cm (3 in) in length, 5 cm (2 in) in width and 1.75 cm (1 in) in thickness. In multiparous (those who have previously borne children) the uterus is still larger and its shape remains variable.

The uterus consists of (i) the fundus, (ii) the body and (iii) the cervix. The fundus is the upper part of the uterus situated between the two fallopian tubes. The body forms the greater part of the organ and is the portion between the fundus and the cervix. The cervix or neck is the lowest portion, part of which projects like an inverted dome into the vagina below. It is traversed by a canal opening above into the cavity of the uterus by an orifice called the internal os, and below into the vagina by the external os.

Attached to either side of the fundus of the uterus are the hollow fallopian tubes (oviducts). The cavity of the uterus has, therefore, three openings – one into each fallopian tube and one through the external os of the cervix into the vagina.

The fundus, the body and the cervix, except for that part which projects into the vagina, are covered on their outer surface by peritoneum. The peritoneum on the anterior surface of the body of the uterus, if traced forward, is found to be reflected on to the superior surface of the bladder. That from the posterior surface lines the lowest part of the pelvic cavity before passing on to the rectum. This space between the uterus and the rectum is called the recto-uterine pouch of Douglas.

The peritoneum passing laterally from the uterus extends to the side wall of the pelvis. It consists of two layers, the front layer being continuous with the peritoneum covering the anterior surface of the uterus and the posterior layer with that covering the posterior surface of the uterus.

This double fold of peritoneum passing from the side of the uterus to the wall of the pelvic cavity is called the broad ligament. Between the two layers forming its upper margin is situated the fallopian tube. It is, therefore, rather like a piece of material draped to hang down on either side of a horizontal pole – the pole being represented by the curved fallopian tube. Also enclosed between the layers of the broad ligament is a fibrous band, the round ligament of the uterus which passes from the side wall of this organ to the inguinal canal.

Structure

The walls of the uterus consist of three layers:

i) The outer serous coat of peritoneum.

ii) The thick middle layer consisting of involuntary, plain muscle (myometrium)

iii) The inner mucous coat called the endometrium.

Functions

i) To receive the fertilized ovum and to retain and nourish the developing foetus throughout the duration of pregnancy.

ii) To expel the foetus at the end of pregnancy by the contractions of its muscular walls.

iii) To play a part in the phenomenon of menstruation.

The vagina

This is a canal with muscular walls 8-10 cm (3-4 in) long which passes in a downward and forward direction from the cervix of the uterus to its lower orifice in the vulva. It is normally collapsed, and the length and diameter of the vagina increased during sexual arousal. The main functions of vagina pertain to serve as the passageway for menstrual flow, as a receptacle for the penis during coital act, and as a part of birth canal.

It is lined by a thin type of skin which is thrown into a number of transverse folds and is kept moist by the secretion of the mucous glands present in the cervix. This secretion is slightly acid in reaction (due to lactic acid). The vagina is the natural home for several microorganisms. Out of these some of the bacteria, fungi and protozoa play important roles in maintaining the vaginal environment.

The breasts or mammary glands

The two breasts are glands which are accessory to the genital system, that is, they take no parts in the actual process of reproduction. They are present in an undeveloped form in the female before puberty as also in the male.

The fully developed female breast, while varying considerably in size, is circular in outline and approximately hemispherical in shape. It lies on the pectoralis major muscle, extending from the second rib above to the sixth rib below and from the margin of the sternum on its medial side to the axilla on the lateral side.

Just below the centre is a small elevation, the nipple, in which the ducts of the breast open. The nipple, in addition, contains a few plain muscle fibers which cause it to become erect when stimulated. The function of the breasts is to secrete milk during breastfeeding. It also serves as a stimulus for sexual arousal in both the sexes. These glands are actually evolved from sweat glands. In humans, though a single pair of breasts persists, in some individuals more than one pair is seen. This condition is called polythelia. It is to be noted that each human female breast is covered by skin and contains a variable amount of fat and the actual mammary gland tissue. The breast size and shape variation occurs due to differences in the amount of fat distribution. The quantity of milk secretion usually does not vary according to breast size.

4.6 PHYSIOLOGY OF MALE REPRODUCTIVE PROCESS

Now we can discuss the physiology of male reproductive process.

In the last sub unit i.e., 4.4 it is clear about the way how the process of spermatogenesis takes place and now we will see the role of hormones in the process.

The hormones which are necessary for spermatogenesis are:

i) Testosterone not only stimulates the process of spermatogenesis but is also necessary for the formation of secondary spermatocyte from primary spermatocyte.

ii) Follicle stimulating hormone (FSH) in addition to testosterone is also necessary for the stimulation of the process of spermatogenesis.

iii) Luteinizing hormone (LH) is essential for the secretion of testosterone from Leydig cells.

iv) Estrogen secreted by Sertoli cells is also necessary for the process of spermatogenesis.

v) Growth hormone (GH) is essential for the general metabolic processes in testis. It is also necessary for the proliferation of spermatogonia.

The above mentioned hormones act at different stages of spermatogenesis.

Endocrine Function of the Testis

Male sex hormones are called androgens. Testes secret three androgens,

i) Testosterone

ii) Dihydrotesterone

iii) Androstenedione. Testosterone is secreted in large quantities by testes and by adrenal cortex in small quantity.

Functions of Testosterone

In general, testosterone is responsible for the distinguishing characteristics of masculine body. In the foetal life, the testes are stimulated by human chorionic gonadotrophins secreted by the placenta. But in childhood practically no testosterone is secreted approximately until 10–12 years of age. Afterwards the

testosterone secretion starts and it increases rapidly at the onset of puberty and lasts throughout most of the remaining part of the life. It is also essential for the growth of the external genitalia – penis, scrotum and other accessory sex organs – genital ducts, seminal vesicles and prostate.

4.7 PHYSIOLOGY OF FEMALE REPRODUCTIVE PROCESS

Before actually having a glance on female reproductive process we shall try to know about functions of the female reproductive organs. The functions of the female reproductive organs are directed to the following ends:

i) The formation of ova or ovulation.

ii) The preparation of the uterus to receive the fertilized ovum.

iii) The retention of the fertilized ovum within the cavity of the uterus until a mature foetus is formed, capable of leading an independent existence, i.e. pregnancy.

iv) The expulsion of the mature foetus, i.e. labour or parturition.

In the young female child, these processes are in abeyance. At a variable age, as a result of the activities of the ductless glands, preparation for the reproductive period in a woman's life commences and is called puberty. The period during which reproduction is possible usually extends from the early teens until the age of forty-five to fifty, when it ends in the menopause (climacteric or 'change of life'), after which pregnancy does not occur.

Ovulation

Now you will know about the ovulation and its role in reproductive process. The ovary contains many thousands of eggs or ova which lie dormant until the onset of puberty. Active changes then take place in the ovary which results in the periodic discharge of an ovum at intervals of a month.

A graafian follicle is a small cystic sac containing fluid and having the ovum attached to its wall, which comes gradually to the surface of the ovary and ruptures about two weeks after the commencement of the last menstrual period.

The ovum therefore actually passes into the peritoneal cavity but is soon caught up in the fimbriae of the fallopian tube which closely surround the ovary. By the action of the ciliated epithelium of the fallopian tube, the ovum is carried slowly towards the cavity of the uterus. Within or little over ten days this stage of journey of the ovum towards the uterine cavity is completed.

The ovum is either fertilized, in which case it becomes embedded in the wall of the uterus and commences to grow into an embryo; or else it is discharged unfertilized from the uterus in the menstrual flow.

Certain changes take place in a graafian follicle after its rupture and it becomes a solid yellowish body called the corpus luteum. This body goes on developing until the next menstrual period, when it gradually disappears and is replaced by fibrous tissue. If the ovum is fertilized, however, the corpus luteum persists throughout pregnancy and, it will be recalled, acts as a gland of internal secretion, producing the hormone progesterone.

Our next concern is to know about the relevance of menstruation. This is a function of the uterus established at puberty (average age, 12 to 13 years) as a result of ovarian activity and consists of the periodic discharge of blood from its cavity. It occurs on an average of every twenty-eight days until the menopause or climacteric is reached, and lasts for three to five days. The amount of fluid, which consists of blood, mucin and epithelial cells, varies between 90-200 ml (3-7 fl. Oz). Menstruation ceases during pregnancy and is often not reestablished until lactation is completed.

The purpose of the monthly cycle is to prepare the mucous membrane of the uterus (endometrium) to receive a fertilized ovum. The endometrium undergoes constant changes between one menstrual period and another and these changes are made in preparation to receive the fertilized ovum. They are largely brought about by the Follicle-Stimulating (FSH) and the Luteinizing (LH) hormones secreted by the pituitary gland, and by estrogen and progesterone secreted by the ovary. Menstruation is really a clearing up of these changes in the endometrium when no fertilized ovum has arrived, and therefore in this sense it gives the endometrium an opportunity to make a fresh preparation.

These changes are described as the menstrual cycle and may be conveniently divided in the following way:

1) The secretory (pre-menstrual) phase, lasting for about 14 days before the period, during which the endometrium becomes thickened and congested and is in a state of preparedness to receive a fertilized ovum.

2) The menstruation period (three to five days) in which some of the epithelium of the uterine mucosa is shed and is accompanied by bleeding. In other words, no fertilized ovum has been received and the work of preparation has been useless.

3) The stage of repair begins in the third or fourth days of the menstrual cycle.

4) The growth phase starts on the fourth day and continues up to fourteenth day before the next secretory phase.

4.8 BIOLOGICAL ASPECTS OF HUMAN FERTILITY

Before actually proceeding to know about the biological aspects of human fertility, it is essential to know about the definition of fertility. Fertility is generally indicated by the actual reproductive performance of a woman or group of women. At the same time, we should know about the other related term 'fecundity'. Fecundity is the biological potential, i.e. the physiological capacity for reproduction. The absence of this potential is known as infecundity. Fertility can be described as the phenomenon of giving birth to children.

Now let us see how biological factors are responsible for the fertility among human males and females. Biological factors play a very important role in determining fertility. The onset of menarche in proper time, regular production of healthy ova, the production of sufficient number of healthy sperms among the males, etc. are important factors. The other biological factors influencing fertility

are health and disease, food habits, etc. Furthermore, genetic factors play an important role on human fertility, as well.

4.9 RELEVANCE OF MENARCHE

Now you will know about the importance of Menarche and its role in the reproductive process. Menarche is the first menstrual cycle, or first menstrual bleeding, in human females. From both social and medical perspectives it is often considered the central event of female puberty, as it signals the possibility of fertility. Girls experience menarche within a range of different ages after attaining puberty. The timing of menarche is influenced by female biology, as well as genetic and environmental factors, especially nutritional factors. The average age of menarche has declined over the last century but the magnitude of the decline and the factors responsible remain subjects of contention.

Menarche is the culmination of a series of physiological and anatomic process of puberty. During this period, a number of physiological changes occur in the girl's body wherein secondary sexual characters appear. Menarche as a discrete event is thought to be relatively a chance result of the gradual thickening of the endometrium induced by rising but fluctuating pubertal estrogen.

Puberty signals the onset of adult sexual life, and menarche means the inception of menstruation. At the start of about 8 years and usually terminating at the onset of menstruation between ages 11 and 16 years i.e. at an average age of 13 years, there is a gradual increase in gonadotropic hormone secretion by the pituitary causing the period of puberty.

In the female, as in the male, the infantile pituitary gland and ovaries are capable of full function if appropriately stimulated. However, as is also true in the male and for reasons not understood, the hypothalamus does not secrete significant quantities of growth hormone during childhood. Experiments have shown that the hypothalamus itself is capable of secreting this hormone, but there is lack of the appropriate signal from some other brain area to cause the secretion. Therefore, it is now believed that the onset of puberty is initiated by some maturation process that occurs elsewhere in the brain, perhaps somewhere in the limbic system.

4.10 RELEVANCE OF MENOPAUSE

Now we can discuss about the menopause and its role in reproductive biology of human beings. Menopause is a period of permanent termination of the primary functions of the human ovaries, which are the ripening and release of ova and the release of hormones that cause both the creation of the uterine lining and later detaching of the uterine lining (a.k.a. the menses). Menopause is generally experienced in women during their midlife, which is late 40s or early 50s. This marks the end of fertile phase of a woman's life.

There is major decline in the production of female hormones by the ovaries during the change from reproductive to non-reproductive phase. It is not abrupt but phases over a period of years and is accepted to be a natural consequence of ageing. However, variations in the transition phase have been observed amongst women. In some women the accompanying signs and effects can significantly

disrupt their daily activities and their sense of well-being. In addition, menopause at younger age is experienced by women who have some sort of functional disorder which affects their reproductive system (i.e., endometriosis, polycystic ovary syndrome, cancer of the reproductive organ). These functional disorders considerably hasten the menopausal process and result in health problems both physical and emotional in the affected woman.

Now we can see the changes that occur in the physiological and psychological aspects among the women. At this age, women should be ready to invite menopause by making their mind. In certain cases counseling is also necessary. At the time of menopause, a woman must readjust her life from one that has been physiologically stimulated by estrogen and progesterone production to one devoid of these hormones. The loss of the estrogens often causes marked physiological changes in the function of the body, including (1) 'hot flushes' categorized by extreme reddening of the skin, (2) psychic sensations of dyspnea, (3) irritability, (4) fatigue, (5) anxiety, (6) occasionally various psychotic states, and (7) decreased strength and calcification of bones throughout the body. In 15% of women, these symptoms are of adequate measure to warrant treatment. If counseling fails small quantities of estrogen reverses the symptoms and with gradual tapering of the dose the postmenopausal women is likely to avoid severe symptoms.

4.11 OTHER BIO-EVENTS TO FERTILITY

Here we can discuss the effects of few biological factors on human fertility. These factors include contraception, abortion and sterilization. All these factors are so important that these need careful study. In every society, now-a-days there is a tendency that family should be small, population explosion should be checked.

i) *Contraception*

Contraceptive practices affect fertility by decreasing the chance of conception. There is a considerable variation in the effectiveness of practicing contraceptive methods as projected in theory and while in actual use. Effective rates of more than 95% are reported using contemporary methods such as oral pills and intrauterine devices. Older methods such as condoms and diaphragm can be more than 90 per cent effective, when used regularly and correctly, but their average use effectiveness is lower because of irregular or incorrect use. Natural methods of contraception viz. withdrawal or abstinence are also in use with variable degree of effectiveness in human groups

ii) *Abortion*

Induced abortion diminishes fertility by terminating pregnancy not by affecting fecundability. Practice of abortion in human societies dates back to ages and is rather common in some settings. Statistics reveal that officially registered percentage of pregnancies terminated by abortion is more than one-third in some countries and substantial numbers of unregistered abortions are perhaps prevalent even in countries where they report very low rate.

iii) *Sterilization*

The complete elimination of fecundability can be brought about by sterilization. The surgical procedures of tubectomy and vasectomy have become common in

diverse nations and cultures. In USA voluntary sterilization has become the most prevalent single means of regulating fertility, typically adopted by couples who have achieved their desired family size. In India sterilization has been encouraged on occasion by various government run incentive programmes.

4.12 SUMMARY

Reproductive Biology is one of the important subjects in science. Evolutionary biology clearly indicates that the human beings are bi-sexual. As such both the sexes possess different reproductive system and function independently with the help of different hormonal secretions. To study both male and female reproductive systems, it is essential to understand the different organs of males and females. The physiological aspects of these two systems are also very important to understand their functions. Physiology of both male and female reproductive processes mainly involves the secretion of different hormones and their functions at different levels. In reproductive biological studies much emphasis has been laid on the term fertility. Fertility can be described as the phenomenon of childbearing. Both biological and non biological factors play an important role in determining fertility. At the same time we can put stress on two important terms mainly involved in the reproductive process, i.e., menarche and menopause. Menarche can be defined as the first menstrual cycle that a female experiences. Menopause is a term used to describe the permanent cessation of primary functions of the ovaries, thus terminating the reproductive capacity of the female. Contraception, abortion and sterilization are said to be the other factors that control or terminate the pregnancies.

Suggested Reading

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Sample Questions

1) Describe the reproductive physiology of male and female.

2) Write a note on male and female reproductive organs.

3) Explain the role of hormones in female reproductive system.

4) Explain the importance of menarche and its role in reproductive process.

5) Examine the relevance of menopause in reproductive process.