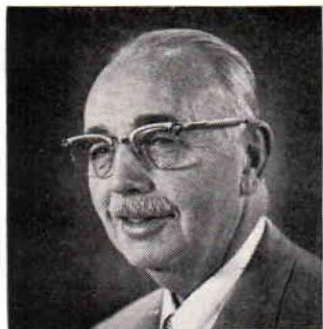


Growth Potential in Children



By CLAUDE N. LAMBERT, M.D.
Professor of Orthopaedic Surgery
University of Illinois, College of Medicine;
Lecturer in Orthopedic Surgery
Northwestern University Medical School

The question of growth potential in a child has always been of interest and only recently have the Orthotists and Prosthetists begun to inquire more about this. They have become interested chiefly due, I believe, to the marked increase in juvenile patients in the amputee programs and to a slightly lesser but still important orthotic problem. With the decrease in *poliomyelitis*, the orthotists perhaps will not see as many new cases but, on the other hand, will still be faced with bracing of those children who did have polio and are still in their growing years.

To open the discussion on growth potential I should like to quote from *Pediatrics* by L. Emmet Holt, Jr. and Rustin McIntosh, pages 13 to 17 as follows:¹

"Growth in height is more slowly responsive to untoward influences than growth in weight. In infancy the measurement is a difficult one to make with accuracy; in older children height assumes increasing importance. A serial record of both weight and height, preferably a graphic one, is an important part of a child's health record and may give the first clue to the pressures of chronic illness.

"The puberal increment in height and weight is much more abrupt than inspection of average curves would indicate. Since puberty occurs in widely different ages in the individual members of any group of normal children, the sharp peaks in growth become blurred when averages are constructed.

"The prediction of ultimate adult height is a matter of concern to especially tall or especially short children and even more so to their parents. It can be said in general that the average height of a man is slightly more than double his height at two years and that the average height of a woman is slightly less than double her height at two years. However, the error associated with a prediction based on such limited information is large. Bayely has shown that after the age of eight years more accurate predictions can be made if skeletal age is considered, since physiologically mature children are taller than others. Such children cease growing earlier, however, and so do not become unusually tall adults. Early adolescence is associated with relatively precocious physical growth in height and epiphyseal ossification and with an early puberal growth spurt and early cessation of growth. Individuals who mature late are also late in these features of growth and, since they grow for a longer period of time, may ultimately become average or even

tall adults. Girls who mature late have somewhat less feminine body proportions than do girls who mature early.

Changes in Body Proportions with Growth

"The two most prominent changes in body proportions, are the growth of the extremities as compared with the trunk and the relative increase in the size of the body as compared with the head.

"The relation of the length of the trunk to that of the extremities is disturbed in cretinism, chondrodystrophy and many other forms of dwarfism. A rough index of this relationship is that of the ratio of what may be called the 'upper measurement' (crown to symphysis) to the 'lower measurement' (symphysis to sole). This ratio decreases from about 1.7 at birth to 1.0 at 10 years, after which it does not change much. When a question of chondrodystrophy or other disease affecting the growth of the extremities arises, one may obtain more accurate measurements from roentgenograms, taken at a tube distance of 6½ feet (2 meters).

"The relation of body length to width changes less conspicuously. The body tends to become more linear up to the time of puberty and broader thereafter. Coincident with the increased activity of children after they learn to walk there is a marked change in their appearance and the transition from the aspect of an infant to that of a young child may be abrupt.

"The head, like the brain, grows rapidly during infancy but even then does not keep pace with the rest of the body, and its subsequent growth is slow. It is important to follow the growth of the head during infancy by means of measurements of its greatest circumference. Undue increase in the size is usually the result of hydrocephalus; occasionally it is caused by subdural hematoma, neoplasm, megacephaly or disease of the bones of the calvarium. A small head is usually associated with defective development of the brain. . . . In evaluating the size of the head it is useful to compare the circumference with that of the chest or with body length. The head is normally larger than the chest at birth, about the same during the second to six months and smaller in circumference thereafter.

Muscle, Fat and Bone

"Stuart, Hill and Shaw have presented a roentgen technic whereby the shadows cast by the soft and hard tissues of an extremity can be measured. Their standards are useful in evaluating the relative proportions of muscle, fat and bone in cases where marked deviation is suspected. Actual measurement of autopsy material shows that at birth only about 25 percent of the body weight is due to muscle, in adults the average proportion is 43 percent.

Osseous Development

"The appearance and union of epiphysial centers of ossification follow a fairly definite pattern and time schedule from birth to maturity; those can be followed by x-ray. The 'skeletal age' or 'bone age' so determined is used as an index of physiological maturity. Its usefulness as a measure of maturity arises from the fact that the roentgen characteristics which the skeleton will have at maturity are known in advance, whereas the adult values for such numerical measures as height and weight are not. For this reason bone age indicates more clearly than other feasible observations the progress of the child toward maturity.

"Bone age is found to be advanced ahead of chronological age in precocious puberty adrenal hyperactivity, and at times in long continued hyperthyroidism. It is retarded in hypothyroid states and in certain other types of dwarfism; in cretins the retardation is striking. Malnutrition also is known to retard ossification.

"The bone age of girls is considerably ahead of that of boys, the advantages amounting to two years in adolescence. Throughout childhood, children destined to mature sexually at an early age are tall and have an advanced bone age; the converse is true in children destined to mature late. Obese children are apt to be tall and to have a bone age above the mean. Differences between the sexes with respect to bone age are present at birth. It is also of interest that Negro infants display a more advanced state of ossification than do whites.

"The normal variations in skeletal maturation are large, a feature which limits the diagnostic usefulness of the measurement. Bone age may differ from chronologic age by a year in either direction in early childhood and by two years later on without necessarily being abnormal.

"The bone age of an individual may be determined in one of several ways; (1) The total number of secondary centers of ossification seen in roentgenograms of the extremities on one side of the body may be counted and compared with the expected number as given by Sontag, Snell and Anderson. This method is suitable for children with a bone age up to five years. (2) A film of the hand or foot may be compared with a set of outline drawings showing epiphysal development at different ages, as given by Vogt and Vickers. This method is also unsuited to older children. (3) For older children, the times of appearance and union of various centers may be noted and compared with tables given in most textbooks of anatomy. This method is not reliable, because of the paucity of suitable centers and the wide variations in the times for any one center. For older children the best method is that of Todd (as revised by Graulich and Pyle); in fact his Atlas is suitable for use at all ages.² According to Todd, stress should be laid on the size, outline and finer details of structure of all bones, including both the shafts and the epiphysal centers. The Atlas consists of reproductions of x-rays of the hands and wrists of children with average maturation at six month intervals. The film most closely matching that of the child in question is selected by inspection, with consideration being given to all the features that indicate maturation and not just to the number and appearance of the carpal centers."

The Atlas of Todd is perhaps the most universally accepted means of determining skeletal age. This comparison is done at six month increments but is not too simple a comparison. It takes considerable experience to compare properly the individual child's x-rays with those as shown in Todd's Atlas, and variations as much as six months to one year are not infrequent. Thus the actual determination of skeletal age should not be left to a prosthettist or orthotist who would use the determination infrequently but rather to orthopaedic surgeons who are more familiar with all the details.

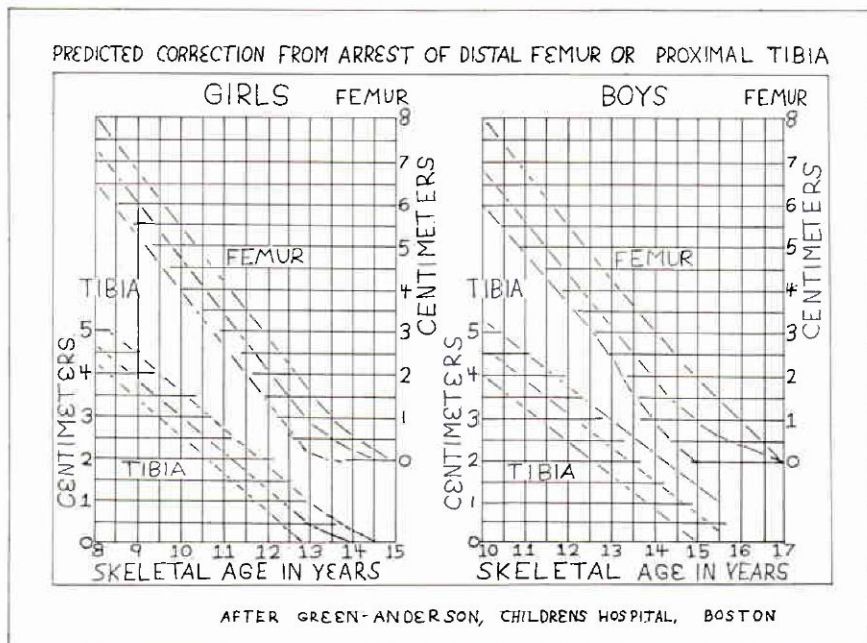
Many other methods or tables have been devised for predicting adult height, knowing the skeletal age of the child, as well as his present height. A very excellent article on this is contained in the *Journal of Pediatrics*, Volume 26, pages 49-64.³ This would make for interesting reading, but the details are so extensive that they almost become impractical except as a research problem. The author does bring out however, several critical points. For example: children who mature early follow a different course of growth than children who mature late, and there are definite sex differences in the patterns of growth of both the early and late matures.

It is definitely known from the studies done at Harvard University that each succeeding generation of entering freshmen at that institution has been taller and heavier. What general factors may have influenced this gradually increasing growth pattern? Better and more nutritious food certainly has

been important. Contrast our present generation of American children with those who were victims of World War II living on barely more than subsistence food, and we see a striking difference in overall growth and development. A second factor is that of better housing, and the third, and, to me, a very important factor is the decrease of childhood infections. The old, severe childhood diseases of scarlet fever, diphtheria, whooping cough and measles have almost been eradicated by means of preventive medicine, vaccination, immunizations, etc. And also the complications of these diseases have been brought fairly well under control. With the advent of the anti-Polio vaccine, this disease in the last four years has almost ceased to exist, but we will still have many of the older cases to observe and to treat in their growing years. And last, but not least, is Tuberculosis. With the advent of antituberculosis drug therapy and earlier diagnosis, much of the severe crippling and deformities associated with this disease are now brought to a minimum. Thus, the child of today has a better chance for normal to increased growth than the child of even ten years ago, because he is not being constantly "knocked down" by the above diseases.

Another factor for our gradual increase in height is the general stress of physical fitness throughout our schools, including grade schools, high schools and colleges, and such programs should be encouraged.

Of particular interest to the orthotist and prosthetist is what can be done to equalize leg lengths when there is a lower extremity inequality. It is quite evident that for prosthetic fitting this inequality often can be made up by merely making that portion of the prosthesis longer as is necessary. Orthotically this is not as easy unless one should use an extension type of brace which cosmetically may not be acceptable. Surgically three things may be done: (1) An attempt to stimulate growth of the shortened extremity. This has not proved very satisfactory. Many different methods of growth stimula-



tion have been tried but the results, at least at the present, are not consistent nor predictable.

Secondly, attempts have been made to do bone lengthening procedures. This has been done by cutting either the femur or tibia and fibula and actually stretching out the bone at the fracture site. This has very limited application. The surgical techniques are difficult and should not be done except by those who are thoroughly familiar with a bone lengthening procedure and are acquainted with all of the potential dangers.

A third method of leg length equalization is that of slowing down or stopping completely further growth in the longer extremity. This, of course, makes the individual shorter in overall height than what he would have been with normal growth, but this decrease in height may be justified by having lower extremities of equal length. This type of procedure can be done by completely stopping growth at one or more epiphyses (usually upper tibia, lower femur or both) or stapling of the epiphysis to slow down growth. This is a very useful procedure when done properly, but here again the skeletal age of the individual must be known, and the further growth potential determined from definite charts as those shown by Dr. Green.⁴

The fourth and last procedure for leg equalization would be to do a bone shortening procedure by resecting and removing a portion of bone usually in the femur to equalize lengths. This procedure has many advocates but of course should not be done until all growth is completed.

In summary the growth factors of children are most important to both the prothetist and orthotist because they see the child outgrowing the appliance in both longitudinal and circumferential growth.

The above discussion has brought out some of these factors in relation to anticipated growth. It must be admitted that this is a very complex problem, and perhaps we should consider the old adage that as far as growth is concerned we are actually a combination of those growth factors given to us by our parents and grandparents.

References

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