Bone Shortening for Inequality of Length in the Lower Limbs

By R. Brooke, F.R.C.S.

Any form of treatment which entails the performance of elaborate operations on a shortened paralysed limb for the correction of various deformities, and possibly the stabilization of a number of joints, must of necessity be incomplete if a child is subsequently to walk with a 2½-to-4-inch patten or cork under the sole of the foot on the affected side. It is not enough that the function of the limb is good and that the child can walk well with a straight spine. The presence of a high cork boot is a very serious drawback both from a physical and a psychological point of view. Treatment is complete only when good function is secured without the aid of an appliance; that is to say, when the lengths of the two limbs are equal. This may be effected by: (1) Limb-lengthening operations. (2) Limb-shortening operations.

There is much to be said in favour of limb-lengthening operations. In some hands good results have been recorded, but considerable apparatus is required, the technique is complicated, and the necessary skill is of no mean order. Finally, the amount of lengthening obtained is often disappointingly small. Limb-shortening operations would seem to be, in the present state of our knowledge, the operations of choice. They have their difficulties, and the least of these are the technical difficulties of the operation itself. More important is the difficulty of deciding (1) the best age at which to perform the operation; (2) the correct amount of bone to remove.

The Most Suitable Age for Operation

It is preferable to operate at as early an age as possible. If stabilization operations have been performed already, so much the better; if they have not, an allowance must be made when calculating the amount of bone to be removed from the sound limb, to compensate for the additional shortening which these operations will entail at some future date.

To operate at an early age is a counsel of perfection which in practice will need qualification. Mechanical difficulties preclude the removal of bone in the very young. In the older child the sooner the operation is performed the sooner the child will be relieved of its appliance, and all the disabilities both physical and psychological which it entails.

Fig. 1 is a graph showing variations in the length of the lower limb in the two sexes at different ages. It is based on Myers' anthropometric measurements of school children and graduates, and is obtained by subtracting the sitting height from the stature. The vertically-hatched area represents the variation in males and the horizontally-hatched area the variation in females. At any age the maximal and minimal lower limb lengths are indicated in the graph by the upper and lower limits of the areas for males and females respectively. The distance between the upper and lower limits represents the degree of variation. It is at once clear that there are marked differences in the degree of variations at different ages and that these variations do not correspond in the two sexes; thus, in the male, the variation is greatest between the ages of 6 and 8 years, and 11 and 14 years, and least between the ages of 3 and 5 years, and 9 and 11 years. In the female, variation is greatest between the ages of 7 and 9 years, and 13 and 14 years, and least between the ages of 3 and 6 years, and 11 and 12 years. These periods of increased variations correspond accurately with periods of increased growth rate.

It is suggested that greater accuracy in estimating the amount of shortening which will be necessary will be achieved if the operation is performed during a period of minimal variation, and for this reason the (3 to 5) 9 to 11 in males and the (3 to 6) 11 to 12 intervals in females are as the time of choice for performing the operation.

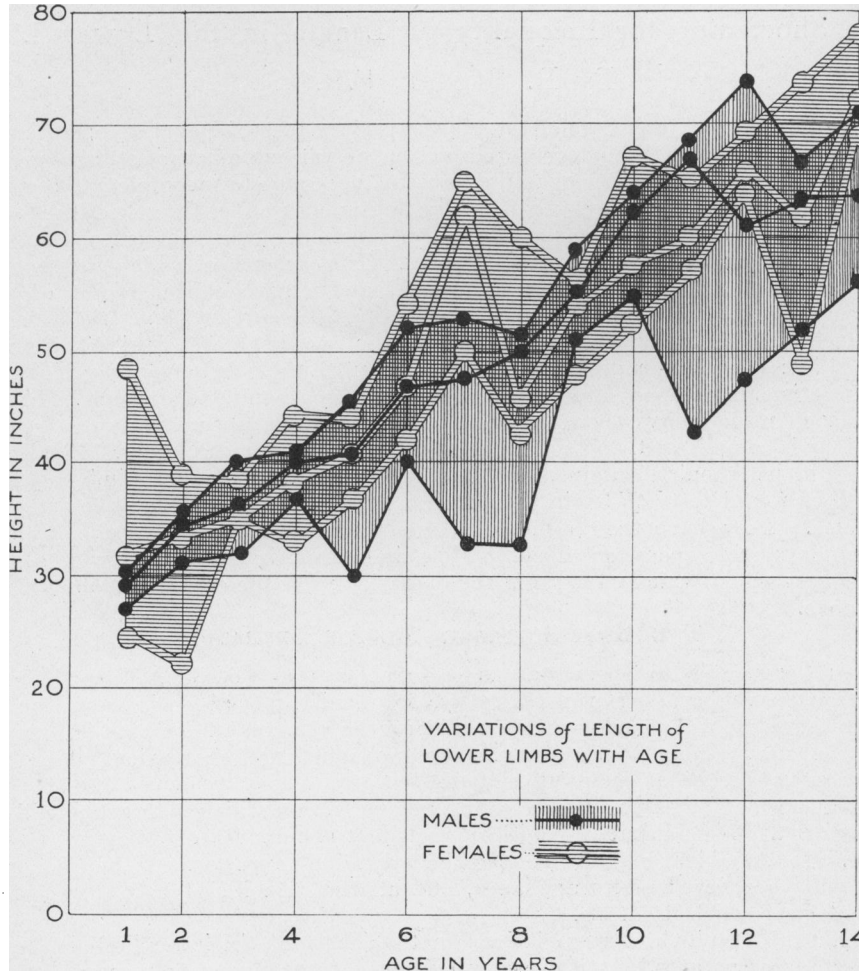


FIG. 1.

HOW MUCH THE LIMB IS TO BE SHORTENED

The amount which the limb must be shortened will depend on whether the cause of the shortening, whatever it may be, is active or not. If it is not, it will be sufficient to remove an amount of bone equal to the amount of shortening which is present. The cases recorded below are examples of limb-shortening operations performed on the growing subject in which subsequent growth of the affected limbs was unimpaired.

If, on the other hand, the cause is still active, it will be necessary to remove not only this amount, but an additional amount equal to the amount of shortening which will be added as the child grows, whenever the cause is active, if limbs of equal length are expected when growth has ceased.

If, at the time when operation was contemplated, the length of the sound limb when the factor causing shortening in the other limb had begun to act, and when growth had ceased, were known and if it were assumed that the shortening factor acted uniformly throughout the growing period, then the amount of growth-lag while the sound limb was growing through a given length would also be known, and the

amount of lag which might be expected while the sound limb was growing through a further known length could be calculated.

Unfortunately the lengths of the sound limb when the shortening commenced and when growth ceases, are unknown, neither is it known for certain that the factor causing the shortening acts uniformly throughout the growing period. Especially is this so in the case of infantile paralysis. So little is known of the cause of the shortening in this disease and the time during which shortening is active. It is, however, possible, by assuming that the sound limbs at these periods are of average lengths, and the factor causing shortening is acting uniformly throughout the whole of the growing period, to calculate the amount of additional shortening which may be expected in any particular case. In this connexion it is unfortunate that no anthropometric measurement of the lengths of the lower limbs is available, and it is necessary to resort to a more laborious process of subtracting the sitting height from the stature, to obtain this information. The work is all the more laborious because the subtracting must be made independently at each age, for the proportional length is different at different ages. Fig. 2 is a graph showing the stature and the lower limb length at different ages. It is at once apparent that the proportion of the stature made up by the lower length at 6 years (A) is different from that at 12 years (B).

The calculation of the amount of shortening which will be required may for convenience be expressed in the form of a formula as follows :—

X = Age at commencement of Disease.
Y = Present age of Subject.
Z = Age when growth ceases.
S = Stature.
Sh = Sitting Height.

Amount of Shortening in ins. required

$$\frac{3(S-Sh \text{ at } Z)-(S-Sh \text{ at } Y)}{4(S-Sh \text{ at } Y)-(S-Sh \text{ at } X)} + \text{Present Shortening in inches.}$$

EXAMPLE *GLENNYS.T.*

I.P. commenced at 1½ years.
Present age 6 years.
Age when growth ceases, 20 years.

Amount of Shortening in ins. required

$$\frac{3(S-Sh \text{ at } Z)-(S-Sh \text{ at } 6)}{4(S-Sh \text{ at } 6)-(S-Sh \text{ at } 1\frac{1}{2})} + \frac{3}{4} \text{ inch.}$$

$$= 2\frac{3}{4} \text{ inches.}$$

The details of the cases mentioned above are as follows :—

Glennys T., aged 6 years, gave a history of a transient attack of fever at the age of eighteen months followed by weakness of the left leg and difficulty in walking. Examined at the age of six years, the left leg was found to be ¾ inch shorter than the right. There was some weakness of the left quadriceps. The shortening was almost completely above the

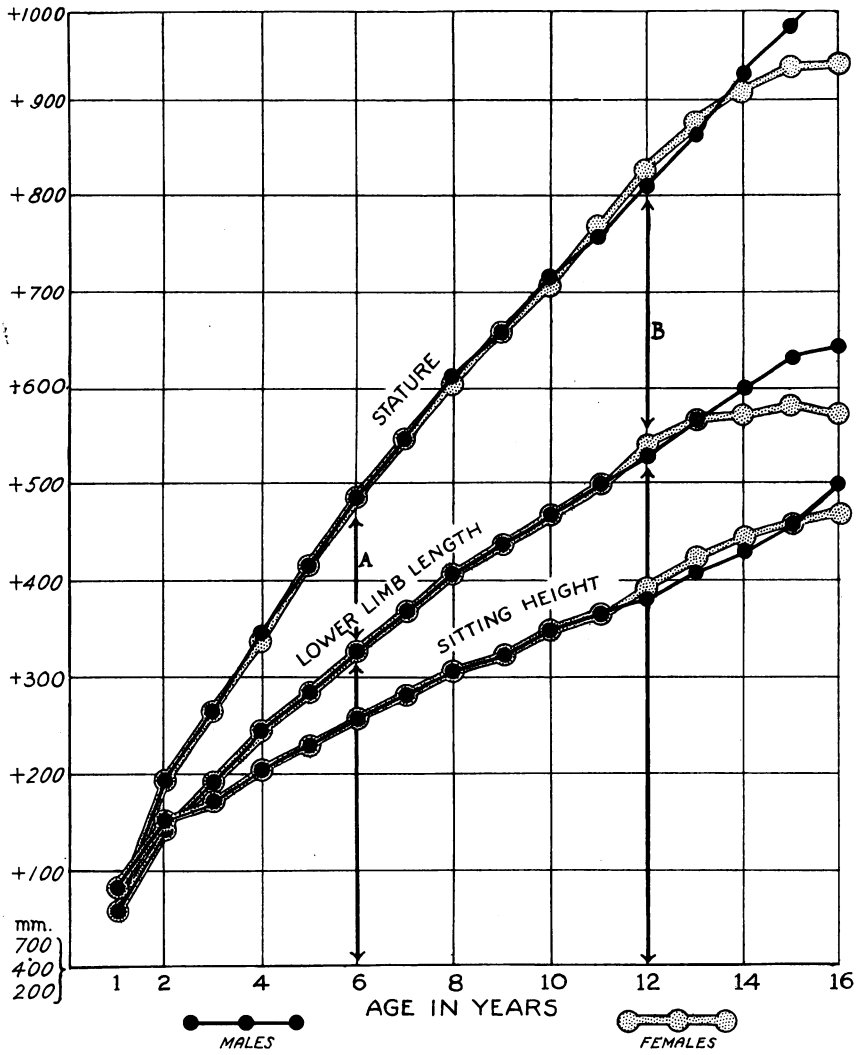


FIG. 2.

knee-joint. The child was of average stature for her age, and as she was in a period of minimal variation, it was decided to perform a limb-shortening operation. Adopting the method of calculation according to the formula above, the amount of shortening was estimated, and $2\frac{3}{4}$ inches of bone were removed from the shaft of the right femur. The ends of the bones were brought into apposition and held there by a small Lane's bone plate. Re-examined at the age of ten years, the right leg was rather more than $\frac{3}{4}$ inch shorter than the left (*see* fig. 3).

Peggy P., aged 13 years, had a left leg $2\frac{3}{4}$ inches shorter than the right. The shortening was above the knee-joint and the shortening factor was still active. It was calculated that in order that she might have an equal limb when an adult, just under 4 inches of bone should be removed from the sound limb. As the child was at a suitable age for operation, $3\frac{3}{4}$ inches of bone was removed from the right femur.

Re-examined at the age of 18 years, the girl is short, but the two limbs are of equal length (fig. 4).

In each of the cases described, lumbar ganglionectomy was perfomed and in all of them the limb became warmer. The increase of growth in length of the limb noted by other observers after the operation, was, in the present series, disappointingly small, so much so, that as far as calculations for limb equalizing operations are concerned, it has been regarded only as a slight plus amount in making any final adjustments that may be thought necessary, and not enough to alter appreciably the calculated figures.

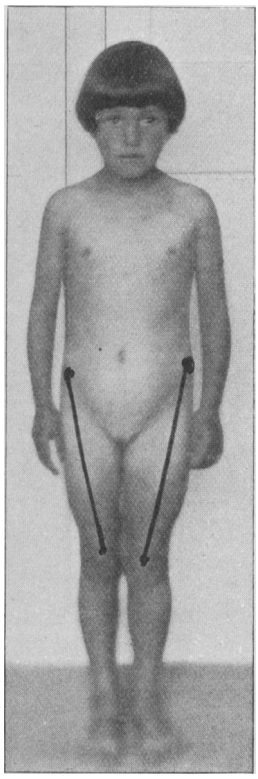


FIG. 3.—G. T., aged 10.

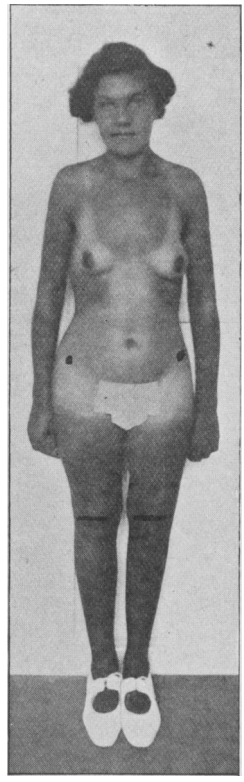


FIG. 4.—P. P., aged 18.

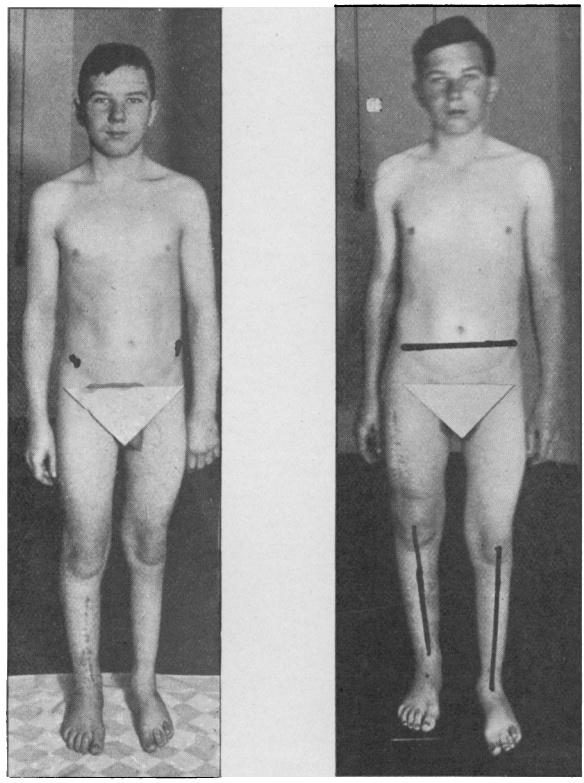
If the shortening is below the knee-joint, the sound limb must also be shortened below the knee, otherwise the level of the knee-joints will be different, causing uneven gait and noticeable in a sitting position. It is very little more difficult to shorten the limb below the knee than to shorten it above the knee. The following case illustrates the limb-shortening below the knee.

Philip G., aged 14 years, gave a history of an attack of infantile paralysis at the age of one year, after which the right leg was weaker than the left. On examination the paralysis was seen to be confined to the calf muscles. There was $1\frac{3}{4}$ inches of shortening of the right leg, chiefly below the knee; the right leg was also blue and cold, and the boy suffered considerably from chilblains in wintertime. In this case chest trouble prevented any active treatment until the age of twelve years, when a right lumbar ganglionectomy was performed. The leg was afterwards much warmer, and all signs of chilblains had disappeared. The right leg was now 2 inches shorter than the left. It was decided to perform a limb-equalizing operation. As no arthrodesing operation was necessary, the amount to be removed was calculated from the previous formula, and a little less than $2\frac{3}{4}$ inches of bone was removed from the shafts of the left tibia and fibula; the ends of the bones were brought into apposition and

those of the tibia fixed by means of an ox bone plate. When last examined two years after the operation, the boy now 14 years old, had the following measurements: The right leg was 29½ inches in length, and the left a little less than 29¼ inches. The left leg was thus still a little more than ¼ inch shorter than the right. The boy was 5ft. 1 inch in height—tall for his age.

If the shortening is both above and below the knee, it will be necessary to remove the bone from the sound limb above and below the knee also. This is illustrated in the following case.

Ronald B., aged 13 years, had an attack of infantile paralysis at the age of 2 years, affecting the left leg above and below the knee. The left ankle and foot were flail, but this deformity had been corrected elsewhere, with excellent results, by a subastragaloid arthrodesis and a posterior bone check operation. When first seen he was 13 years of age. The left leg was 2½ inches shorter than the right. The limb was blue and cold. A left lumbar ganglionectomy was performed, and adopting the calculation previously mentioned, and assuming that the



Aged 14. Aged 15.

FIG. 5.—R. B.

boy would be of average height when an adult, it was calculated that 3¾ inches of shortening to the sound limb would be necessary. Accordingly, three months after the first operation the right leg was shortened 2¼ inches by the removal of that amount of bone from the tibia and fibula, as the boy was now fourteen years old and in a period of minimal variation and growth. The ends of the tibia were brought into apposition and fixed by a Lane's plate, which has since been removed. A little later 1½ inches of bone was removed from the right femur. Re-examined at the age of 15 (fig. 5) the boy is short in stature. The right leg was still just over one inch shorter that the left, as indicated by the pelvic tilting.