Principles of Bracing in the Rehabilitation of the Paraplegic*

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WITHIN recent years it has been commonly accepted that crutch-and-brace ambulation forms an integral part of the rehabilitation of the paraplegic. It is necessary to develop a proper orientation to the subject as a whole and specifically to discuss the methods of attainment of maximal function with minimal bracing.

Four points of view have developed, concerning the degree to which this ambulation can be carried out. There are those who believe that the paraplegic must develop the use of crutches and braces to the point of total ambulation. Some think that the use of the wheelchair as the sole means of locomotion is sufficient. A third group feels that a combination of both of these methods is best. The fourth group, which fortunately has not put its concepts into practice, has suggested that paraplegics would be better off and more adept at handling themselves if both legs were amputated. It would be well, at this point, to analyze all these opinions and to understand the advantages and disadvantages of each.

The last group can be quickly disposed of. It has been the experience of almost all who have worked with paraplegics that in most cases the retention of the lower extremities does not form an insurmountable barrier to the ability of the paraplegic to become self-sufficient. Furthermore, those paraplegics that we have seen, in whom the lower extremities had to be amputated for other reasons, did poorly in comparison to those with similar neurologic lesions who retained their lower extremities.

Ambulation by means of crutches and braces as the sole method of getting around, has proven feasible in a limited number of cases. Generally, these people are slim, athletic and have either conus or cauda equina lesions. This lower motor neuron type of lesion spares the abdominal and back muscles and permits the legs to remain flaccid following spinal shock. There is also a large loss of weight, due to the almost total muscle atrophy occurring in the lower extremities. However, in heavy, spastic individuals who have high lesions there is a limit to the development of muscle power in the upper normal part of the body, and the lower extremities remain heavy and bulky. Crutch-and-brace walking as a total means of ambulation in these cases become a goal almost impossible to attain with any any great degree of efficiency, and is usually accompanied by frustration.

The sole use of the wheelchair as a form of locomotion has definite drawbacks. The paraplegic will require a considerable amount of aid to mount stairs, curbs or other obstacles. There are small areas which are restricted for the paraplegic in a wheelchair; the chief one being the bathroom. The constant use of the wheelchair would

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favor the formation of flexion contractures. And the complete loss of weight-bearing would mean the loss of the most important stimulus for the formation of protein bone matrix. As a result calcium would pour out from the bones, and osteoporosis, urinary calculi, soft-issue ossifications, and even pathological fractures might result[1]. Unrelieved sitting may also produce ischial decubiti.

A combination of crutch-and-brace walking, and wheelchair locomotion is acceptable and practical in a majority of cases because of the following facts:

1. It enables the individual to get into restricted places and to mount stairs and curbs by means of crutches and braces.
2. Ambulation done for several hours a day supplies an excellent form of maximal functional exercise to the normally innervated parts of the body and applies pressure to the lower extremities with concomitant beneficial results on the metabolic processes.
3. Ambulation undoubtedly has a beneficial effect upon spasticity, if it is done religiously.
4. Most vocations require a considerable amount of rapid moving about, and the use of the wheelchair is a distinct time-saver. It also frees the hands to accomplish work.
5. The rapidity and distance which the individual can travel via the wheelchair gives a greater sense of freedom.

The disadvantages of this combined form of locomation are that crutches must be carried on the wheelchair, and the wheelchair may not be available when the paraplegic wants to sit down. The first of these problems may be solved by the use of collapsible crutches which can be stored easily on the wheelchair. The second, however, is a drawback for which the paraplegic himself must find the solution.

It would seem from this analysis that rehabilitation should definitely include at least partial brace-and-crutch walking. With this in mind it is clear that braces should be fitted to

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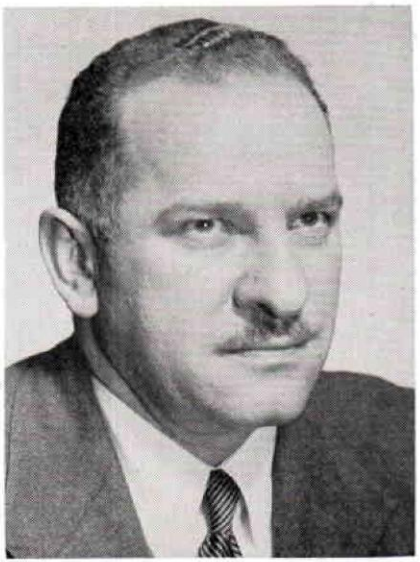

every possible case of paraplegia. Such braces must act purely as splints and should not have any weight-bearing function. Weight bearing braces may produce ulcers due to pressure on anesthetic areas over bony projections, such as the ischial tuberosities, and should not have any weight-bearing function of the bones themselves.

Most publications mentioning the use of braces in paraplegia are of recent origin. The reason for this is obvious, since at no time in the past have paraplegics in large groups lived as long and as healthfully as those produced by the Second World War. In many cases the decision for bracing made by the physician is not accompanied by an interest in their fabrication. Generally, this practice results in excessive and inefficient bracing.

Most frequently long leg braces with a pelvic band or a body brace attached are prescribed. The use of the body brace or pelvic band is objectionable because they are clumsy, are put on with difficulty, consume excessive time, add weight to carry and unless the joints are made with the greatest precision and of special design cannot fit as well sitting as when standing.

Let us consider first the disturbances which these appliances are supposed to prevent. Chief among these is "Jack-knifing" or spontaneous flexion of the hips while standing, due to hip instability or spasticity of the hip flexors. Then there are lateral instability of the hips, outward rotation of the lower extremities and excessive lumbar lordosis. Such lordosis occurs in a paraplegic because in order to be stable in the standing position the hips must be locked against the anterior pelvifemoral ligaments in a strained extended position. Finally, there is also a psychological aspect in the use of these appliances because of the sense of support they give.

With injuries of the upper thoracic region, and even occasionally in lower cervical lesions, there still remain some very important and potentially powerful muscles which are normally innervated and lie below the lesion level. These muscles, the latissimus dorsi and the lower third of the trapezius, if made strong enough by training, can adequately control the stability of the hips by substitution. This can occur when the normal hip stabilizing muscles are paralyzed as long as the lower extremities are splinted.

The latissimus dorsi has its insertion in the upper end of the humerus and its origin from all the spinous processes from D6 down, the sacrum and from the posterior rim of the ilium. The innervation of this muscle comes from C6-7-8 through the brachial plexus and by way of the thoracodorsal nerve. Here is a muscle almost totally below the level of such a lesion in which voluntary motion is retained. The lower third of the trapezius, which also lies below such a level, has its origin from about the 6th to the 12th dorsal spinous processes. Its insertion is the outer end of the scapular spine. Its innervation, being C3-4 through the spinal accessory nerve, by-passes a high lesion. These muscles, when properly trained, can in most cases remove the necessity of using the pelvic band or the back brace.

The latissimus dorsi under ordinary circumstances will adduct, extend and internally rotate the humerus. Were the shoulders to be fixed, the mobilizing end of the muscles would be transferred to the origin. Trapeze artists who fix their shoulders use the latissimusdorsi muscles as a sling to pull the trunk forward and upward[2]. If the feet were fixed to the ground and the knees stiffened this action would actively extend the hips. The paraplegic can perform this action by clamping the axillary rests of the crutches between

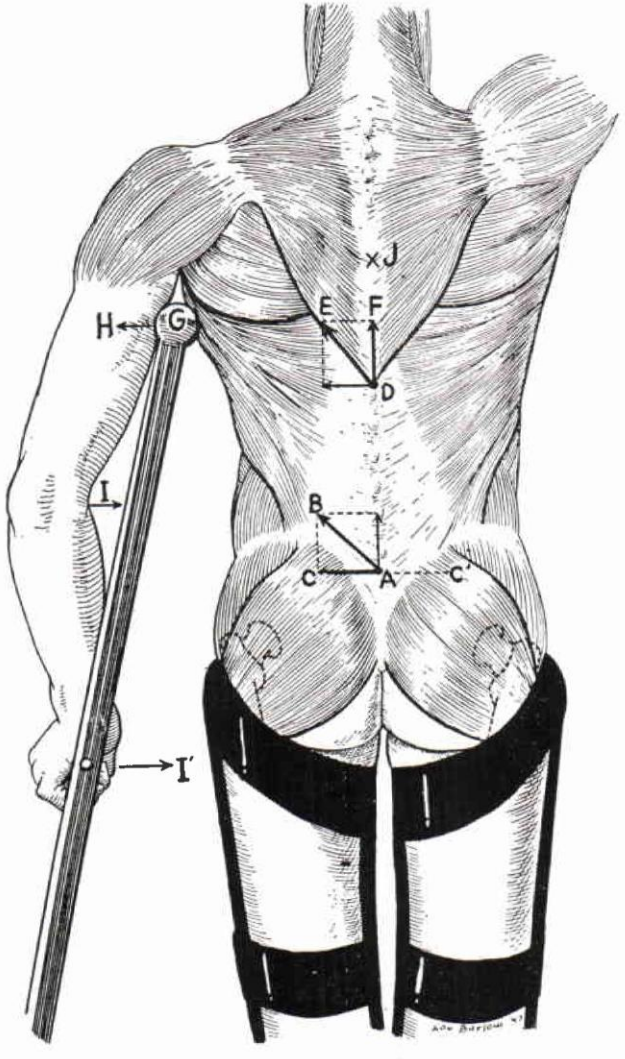

Fig. 1. Resolution of pulling Forces of the lower third of the trapezius and latissimus muscles with fixed insertions show Forces AC and AC^1 which counterbalance each other and produce lateral stability.

humeri and the body thus fixing the shoulders (Fig. II). Besides this forward pull, these muscles have equal and opposite lateral pulls as long as the axillary rests of the crutches are held with equal pressure on both sides. The swaying of the hips from one side to the other can be easily controlled by tensing one shoulder and then the other (Fig. I). We now have active extension of the hips, locking of the hips in extension by means of the anterior pelvi-femoral ligament and lateral stability of the hips. The lower third of the trapezius will follow the same general rule. With fixation of the shoulers the scapulae are fixed. The mobilizing end of this muscle is now transferred to its origin. This muscle can apply an upward pull from the region of the 12th dorsal vertebra or, in other words, from the

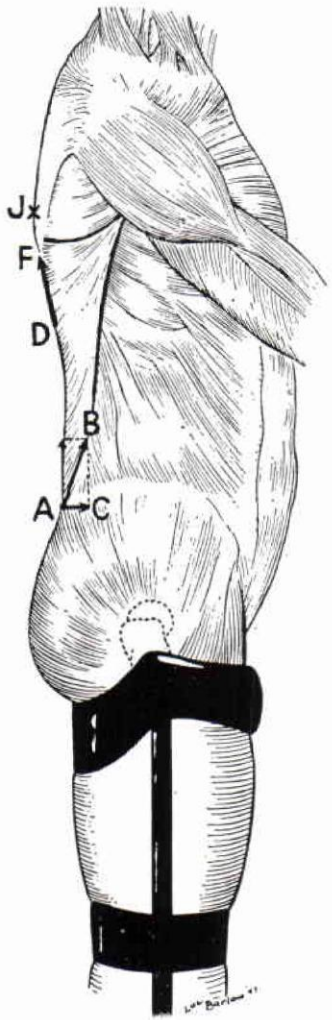

Fig. II. In lateral view Force AC actively extends the hips and Force FD can straighten the lumbar curve.

upper end of the lumbar curve. This pull can straighten the lumbar lordosis (Figs. I and II). It would seem then that these two large normally innervated muscle groups occurring below the level of the lesion have a very powerful influence on the maintenance of posture and stability. This leaves the external rotation of the lower extremities as the sole disturbance to be accounted for.

Many of the braces made for paraplegics have upper posterior thigh bands which are almost transverse. Instead, the thigh band should be made so that it curves upward and outward to fit loosely into the gluteal fold (Fig. I). This can be done if the outer upright is carried to just below the prominence of the greater trochanter (Fig. II). Now when the leg and brace rotate externally, the gluteal mass acts as a soft tissue block to the rotation of the brace. If bracing is so arranged that the foot is kept flat on the ground, much of this external rotation can be prevented purely by friction. In calipers, the

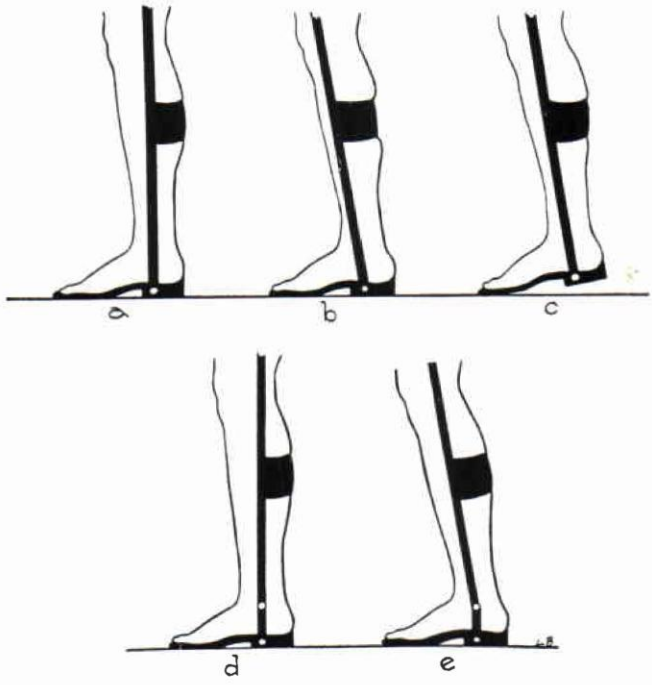

Fig. III. Mechanics of the caliper and stirrup

ankle joint of the brace is placed into the heel, an extremely unphysiological position. Since the paraplegic generally stands leaning forward slightly, the axis of the brace moves forward in relation to the axis of the leg, thus tightening the posterior calf band. Since the calf can give only in a limited fashion to this pressure, the heel must came up thus permitting pivoting to occur on the sole (Fig. III). The stirrup, on the other hand, has the ankle joint of the brace placed at the ankle joint of the lower extremity, a physiological position. Thus, on leaning forward, the axis of the brace moves forward precisely to the same extent as the axis of the leg. There is no tightening of the calf band and no raising of the heel. A combination of a stirrup and a curved upper posterior thigh band is preventive of external rotation. Except for the infrequent cases of internal rotation which do require a pelvic band for prevention, all other reasons for the pelvic band and the back brace seem to be invalid.

There are certain other points to consider in the fabrication of these braces. They should be made so that they can be put on easily and quickly. In order to accomplish this, a minimum amount of cuffs and lacing should be required. A well fitting knee cap can adequately replace all anterior cuffs and straps, except one single narrow anterior strap on the upper end of the brace to prevent the brace falling off the leg when the knee is unlocked. This is in accord with the universal three-point principle with which all braces are manufactured. A point of pressure at the knee and two points of counter pressure, one at the upper posterior thigh band and the other at the posterior calf band or the counter of the shoe can fulfill this principle most efficiently. The knee cap should be loose enough so that the knee, when weight-bearing, should have about five degrees of flexion.

This has been found to reduce the amount of stimuli coming from stretched calf and hamstring muscles in spastics. A heel raise will also reduce the amount of stretch of the calf muscles. Tightly fitting shoes may stimulate the reflexogenic areas of the feet and increase spasticity. Thus shoes should at least be roomy and preferably made of soft leather.

Using these principles, it has been possible to remove all pelvic bands and all back braces from those who had been wearing them for a long time, occasionally for years. And we never attached them to the braces of a new paraplegic. No disturbing results have been observed and the contribution to the paraplegic's efficiency and sense of freedom has been great.

While the picture presented has been that of the paraplegic with the complete anatomical or physiological lesion, the principles elaborated are probably applicable to the incomplete lesion with modifications as necessary. Such modifications should always be in the direction of decreasing the amount of bracing to be used.

CONCLUSIONS

(1) Total or partial crutch-and-brace walking is an integral part of the rehabilitation of the paraplegic.

(2) Pelvis bands and back braces attached to the leg braces are rarely, if ever, necessary.

(3) The latissimus dorsi and the lower third of the trapezius should be trained to replace the functions of these appliances.

(4) The posterior upper thigh band should be curved to fit loosely into the gluteal fold in order to prevent external rotation.

(5) Stirrups, instead of calipers, should be used exclusively.

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ADDENDUM:
TRAINING AND FUNCTIONAL EXERCISE

Besides the latissimus dorsi and trapezius muscles, all other muscles of the shoulder girdle play their roles in stablilizing the trunk of the paraplegic. For example, when these muscles are contracted, the pectoralis and serratus anterior muscles tend to pull the upper part of the trunk backward as the latissimus tends to pull it forward. While the integrated action of all of the muscles of the shoulder girdle are potentially capable of stabilizing the trunk of the paraplegic in the absence of the pelvic band or back brace attached to the long leg braces, only proper training will permit them to act efficiently in this fashion. This training is best obtained in the functional position. The patient stands between parallel bars wearing long leg braces holding the bars in front of him. He repeatedly pulls himself from the hip flexed position to the upright position. This is done by tightening the shoulder girdle muscles while maintaining the elbows at a fixed angle and the position of the shoulders unchanged in space. Under these conditions the shoulder girdle muscles, especially the latissimus dorsi, do the work of bringing the trunk to the upright position. This work is gradually increased by progressively increasing the resistance to the movement by using the maximum-weight low-repetition method of Delorme.

The technique of training is shown in Figure IV. The apparatus is simple, consisting of a padded belt around the pelvis attached to a cable carry-

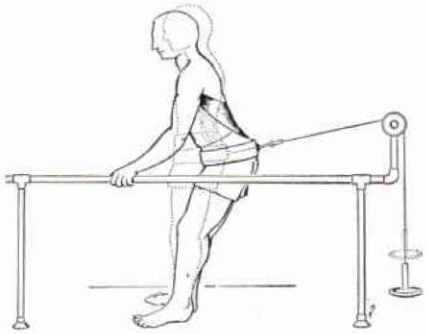

Fig. IV

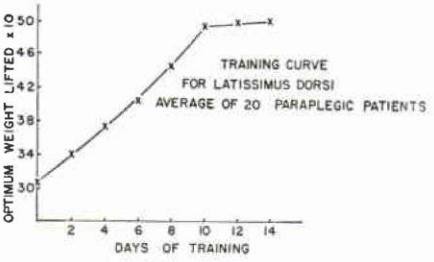

Fig. V

ing weights over a pulley at the end of the parallel bars. The progress of training can be measured by daily observing the maximum weight that the patient can carry ten times from the flexed to the upright position. Figure V shows the progress of the average performance of twenty consecutive cases. Maximum strengthening of the movement can be accomplished within two weeks in a well motivated patient.

For the stability of the trunk to be maintained during ambulation, the lessons learned between the parallel bars must be carried over to crutches. The intermittent elevation of ambulation is done by the piston-like action of the trunk through the shoulder girdle, the elbows being kept at a fixed angle. Throughout this procedure, the muscles are never completely relaxed.

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[2] GRANT, JOHN C. B.: Method of anatomy, Descriptive and Deductive, 3d ed. Williams & Wilkins, 1944. 822 pp.

"What's New(s)"

• Alfred Denison has been named manager of the Chicago office of the *J. E. Hanger Co.* He succeeds the late J. H. Mathis.

• C. E. Yesalis, Sales Manager of *S. H. Camp & Company* is one of several key executives who have bought ownership of the company from the estate of the founder, Samuel Higby Camp. F. I. Yeakey, President and C. B. Clemons, Vice President are among the new owners.

• Paul Deak has bought the *New Haven Surgical Company*, New Haven, Conn., from the former owner, J. A. Ganzke. Mr. Ganzke has retired and is now living in Florida.

• Joseph Spievak of the *Youngstown-Spievak Limb Company* sends word that William Kaiser, Certified Prosthetist, has rejoined his staff after an absence of six years.

• The *B. Peters Company* is now occupying enlarged quarters with new and modern facilities at 1127 S. Broad Street in Philadelphia.

• The *L. Laufer & Company* has been named sole Eastern distributor of Naugalite. The company also offers 1/8" Kemblo and all nylon stockinette, in addition to Naugahyde, which has been approved by the Navy for use in soft sockets.