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PART III

LOWER EXTREMITY BRACING IN PARAPLEGICS WITH USAGE FOLLOW-UP

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INTRODUCTION

TEN years ago at Craig Rehabilitation Hospital, Denver, Colorado, Drs. John Young and Robert Jackson; Miss Pat Rogge, Chief Physical Therapist; and Mr. Bruce Scott, Orthotist, felt there had to be a better method of lower extremity bracing for the paraplegic with a complete neurological level above L1. The brace to be described and critiqued by the users was developed by the aforementioned people over the past decade, primarily by trial and error, plus the greatest teacher of all, experience.

The brace takes greater advantage, than standard bracing does, of a universal premise, Newton's Third Law of Motion. Action and reaction are equal and opposite. The crux of the brace is the solid shoe-ankle component, thus giving one fixed point of balance, and the reaction from the floor is not dissipated at the ankle. From an orthotic standpoint, the main difficulties encountered were strength and stability within the shoe and ankle mechanism. Many breakdowns in various parts of this component were encountered until the following design was adopted two years ago. No further construction problems have arisen.

MATERIALS AND METHODS

Taking the brace from the bottom, the existing outsole is removed from the shoe. A high carbon, spring steel plate ($\frac{1}{8}$ inch thick and $1\frac{1}{8}$ inch wide), shaped to the contour of the insole from the heel and extending $\frac{1}{2}$ inch distal to the metatarsal heads, is imbedded in the insole (fig. 1). An outsole of hard oak-tanned leather is stitched to the welt. Imbedded into this sole is a transverse, high carbon, spring-steel plate ($\frac{1}{8}$ inch thick and $\frac{5}{8}$ inch wide). The length goes completely across the metatarsal heads to give mediolateral stability and to prevent the shoe from warping. One rivet passes through the centre of the transverse plate through the first outsole, the previously mentioned longitudinal plate and insole. An extra strut, made of cold rolled steel ($\frac{1}{8}$ inch by $\frac{5}{8}$ inch) is welded at three points to a double Klenzak stirrup. The welds are at the heads of the stirrup and the distal point of the stirrup shank. The stirrup complex is also riveted into the first outsole, through and through on either side of the longitudinal plate and proximally and distally on the stirrup shank. The mediolateral rivets do not weaken the longitudinal plate (fig. 2). For total contact with the floor and to eliminate stress factors between the breast of the heel to the transverse plate, a wedge-shaped leather soling is then put over the stirrup complex. This gives a

flat surface and the necessary heel lift. Semi-firm sponge rubber, to act as a cushion at heel strike, is inserted into the posterior aspect of the heel, extending approximately $\frac{3}{4}$ inch distally, and this is the same thickness as the first outsole (fig. 3). Finally, a second outsole, or top lift, of $\frac{1}{8}$ inch Neolite is glued to the leather outsole and wedge. The purpose of this is to cover the wedge and for

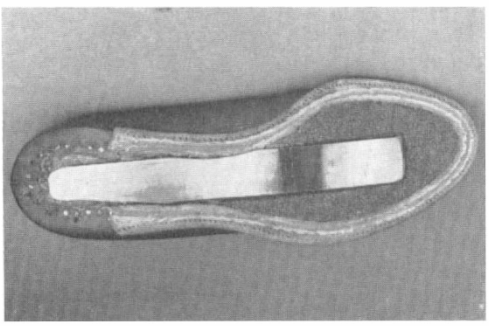

FIG. 1

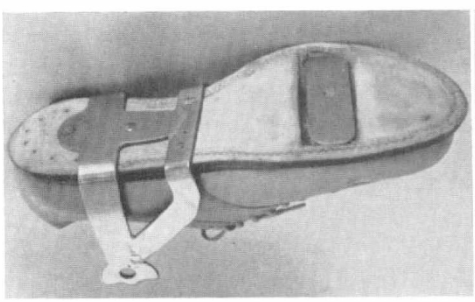

FIG. 2

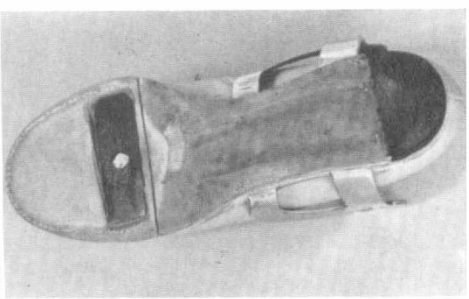

FIG. 3

wear and flexibility (fig. 4). As each of these components were added, the durability and stability of the shoe and the ankle joint improved. The springs in the double Klenzak ankle joint are replaced with solid pins which can be adjusted. With the rigid ankle, the principle of standing and gaiting is accomplished by moving the centre of gravity anteriorly by hyperextension of the hips. As the forces are moving anteriorly, a solid anterior tibial band is all that is required to stabilise the knee. This band is contoured to the tibial ridge and heavily padded with high-density sponge rubber to distribute the pressure widely and evenly. The band is hinged and has snap locks for ease of donning and doffing (figs. 4 to 6). Continuing to move proximally, both medial and lateral uprights are offset posteriorly $\frac{3}{4}$ inch at the knee joint. The forces are applied to the knee joint in extension alleviating the stress and strain on the locking mechanism and making it easier to unlock. The offset knee joint was originally designed to be used as a functional long leg brace, the same as a prosthesis. Even though walking with the braces locked at the knees, this principle is retained for the very simple reason that there are no sharp, protruding edges with the knees flexed while sitting, thus saving

wear and tear on trousers. A Bale lock with a positive adjusting spring load is used at the knee for locking and unlocking (figs. 6 to 8). An inferior thigh cuff is generally not required. The superior thigh band is slanted inferiorly to avoid ischial weight bearing and to distribute pressure more evenly (fig. 5). The band is solid posteriorly and has a ring strap with Velcro closure, again making the brace easy to don and doff. The uprights are made of aluminium and the medial upright is lowered to decrease stimulation of the adductor longus. Even with flaccid extremities it was found that this shorter upright was more desirable (fig. 6). In essence, the brace follows the three-point pressure principle, that is the superior posterior thigh band, the anterior superior tibial band, and the posterior aspect of the shoe.

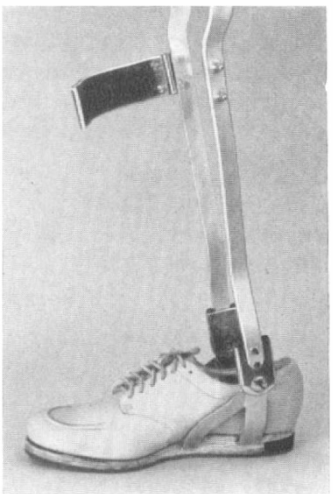

FIG. 4

Shortly after spinal cord injuries, most patients want to be braced immediately so they can 'walk again'. Early bracing has great psychological value following complete spinal cord injury. As time passes without neuromuscular return and the individual finds ambulation in wheelchair much more convenient than crutch-brace ambulation, the show is on the other foot, and then the important physiological reasons for crutch and brace ambulation are stressed. These are: stressing the long bones of the lower extremities, which

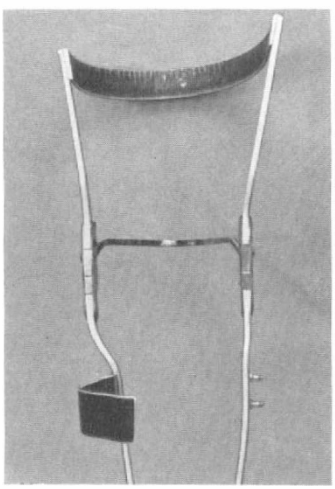

FIG. 5

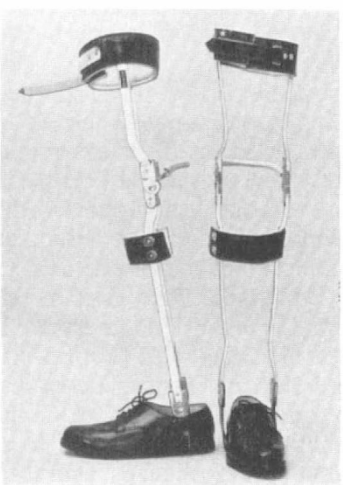

FIG. 6

certainly must forestall osteoporosis of disuse; standing in hyperextension at the hips is a form of active range of motion and decreases the chance of contractures, as it reverses the sitting curves encountered in the wheelchair; improves vascular tone of the lower extremities; and cannot help but the excellent exercise for the

cardiopulmonary system. If the individual wears the braces and they are used only once or twice a day in situations that will not accommodate a wheelchair and so he maintains psychological independence, it is well worth the effort. With passage of time, functional ambulation is relegated to a secondary position by the majority of patients. They hopefully then use the braces for physiological reasons.

In a typical case, gait training starts approximately seven weeks post-injury with a Jewett type hyperextension back brace, the long leg braces, and Canadian type crutches. At about three months post-injury, the Jewett is exchanged for a padded Hoke corset and in lower neurological lesions the corset is discontinued

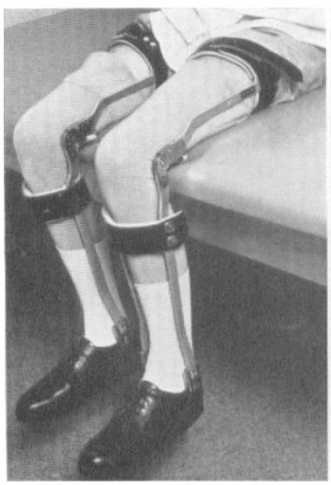

FIG. 7

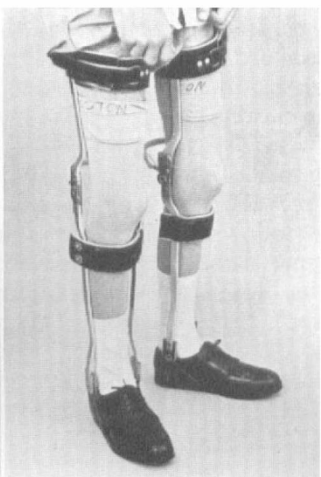

FIG. 8

as soon as possible. The physical therapist adjusts the ankles by altering the screws and pins in the double Klenzak ankle joint while the individual is standing in parallel bars. Setting the exact amount of ankle dorsiflexion is more of an art than a science. The individual's centre of gravity is found and he then has relaxed balance stance without arm support within a few minutes of putting on the braces (fig. 8). A swing-through gait with Canadian type crutches is taught with the therapist walking behind and pushing anteriorly at the hips to insure hip hyperextension on heel strike. A pelvic band is never required. Wheelchair transfers are taught immediately. The knees are locked in extension and the patient comes straight out of the chair with postero-inferior force on the crutches into balanced hyperextended stance. Sitting down is exactly the reverse, the knees unlocking automatically on the anterior edge of the wheelchair seat. When the individual has gained confidence in his ability to solo, training then encompasses all types of terrain, climate, ramps, curbs, stairs, falling, and getting up from a fall. Swing-to, side steps and turns are taught. A four-point gait is slow and energy consuming and is only taught to prove to the patient that this is so. By achieving instant balance and thus eliminating time-consuming parallel-bar work, gait training and expensive hospitalisation time is much reduced. The average time for a typical case to solo is two weeks and for complete training is four to six weeks. The rapid physical progress is psychologically beneficial to the patient.

The indications for bracing are very simple, that is, upper extremities and shoulder girdles adequate to handle crutches and motivation on the part of the individual to have a go at it. The average patient, during his first six weeks post-injury, is on a Stryker frame in the gym doing upper-extremity strengthening exercises and is motivated by observing other patients further along in their programme than he is.

RESULTS AND DISCUSSION

Questionnaires were sent to the last 75 L1 or above paraplegics for whom these locked-knee braces were prescribed. All had no volitional knee extension and so their braces were never changed to functional long-leg or short-leg braces. Questionnaires were purposely not sent to patients who enjoyed neuromuscular return below L1 and whose braces were modified, as their answers would obviously weight the series favourably.

PARAPLEGIC LOWER EXTREMITY BRACING QUESTIONNAIRE STATISTICS

75 Sent. 52 Answered.
7 Returned Unanswered. 16 Not Returned.

Sex and Age (47 Men—5 Women)	*Complete Neurological Level*
19 were 15-19 years old	8 were C8-T5
15 were 20-29 years old	11 were T6-T9
18 were 30-51 years old	33 were T10-L1
Year of Onset of Paraplegia	*Year Braced*
10 before 1965	6 before 1965
5 in 1965	3 in 1965
10 in 1966	7 in 1966
14 in 1967	17 in 1967
12 in 1968	14 in 1968
1 in 1969	5 in 1969

It is realised that a questionnaire of this sort, with subjective questions, is open to considerable interpretation by the patients. Indeed, a few questions were answered incongruously by the same individual. Albeit, the questionnaires purpose was served, that is, to show trends. The multiple choice questions and the number of patients responding to each possible selection were as shown in the questionnaire on next page.

The response to question 1 speaks well for the brace design and I believe this simple point is one of the most important, as patient acceptance is necessary before the braces can be used. This undoubtedly accounts for the fact they do not become 'hang on the wall' or 'sit in the closet' braces. As with all things in life, if they are troublesome, it is human nature to find an excuse not to do them. The ease of putting the braces on and off contributes to their successful use.

Question 2 could have been worded more precisely, but, be that as it may, at least 47 our of 75 are wearing the braces. Of the 21 who wore the braces all day, 19 walked at least once a day and 2 at least once a week. Of the 26 who

rarely wore the braces, 9 stated they walked with braces at least once a day, 15 at least once a week and 2 commented they used the braces for standing only. The latter 2 account for the seeming discrepancy between 2 (*c*) and 3 (*c*).

QUESTIONNAIRE

1. I find the braces ( ) to put on and take off:			
	(*a*) Easy		46
	(*b*) Hard		6
2. I wear the braces:			
	(*a*) All day	21	47
	(*b*) Rarely	26	
	(*c*) Never		4
	Not answered		1
3. I walk with the braces:			
	(*a*) At least once a day	28	45
	(*b*) At least once a week	17	
	(*c*) Never		6
	Not answered		1
4. I walk:			
	(*a*) Solo with crutches	26	49
	(*b*) With someone helping me	11	
	(*c*) In parallel bars	12	
	Not answered		3
5. I can walk:			
	(*a*) A few yards	13	48
	(*b*) As much as I want	35	
	Not answered		4
6. I ( ) go up and down stairs:			
	(*a*) Can		33
	(*b*) Cannot		17
	Not answered		2
7. I have ( ) repairs done on the braces:			
	(*a*) Never had any		32
	(*b*) Had a few		17
	(*c*) Had many		2
	Not answered		1
8. If I had to do it over again, I ( ) to be braced:			
	(*a*) Would like		48
	(*b*) Would not like		3
	Not answered		1

In question 4, one of the 'standers' plus 3 who never wear the braces account for the extra 4 who answered how they walked. Generally speaking, the ones who could not solo were the higher neurological lesions and it was gratifying to learn that at least 23 of them (4 (*b*) and (*c*)) were using the braces for physiological reasons only.

Question 5 is not a very scientific question, but the 35 who stated they could

walk 'as much as I want' speak well for the minimum energy expenditure involved in ambulating with a solid shoe-ankle component. The solid ankle also decreases the amount of clonus an individual would have with a floppy ankle. The average weight of a pair of braces with shoes is 11·5 pounds.

Question 6 was a purposely worded catch-question, as going up and down stairs is the most difficult manoeuvre. I hoped it would correlate with the solo and helped walkers (4 (*a*) and (*b*) = 37) and those who felt they could walk 'as much as I want' (5 (*b*) = 35). I feel the slightly fewer number of those who could go up and down stairs (6 (*a*) = 33) does validate the braces' use.

The 32 who never had repairs in question 7 can be interpreted two ways. They either are not being used very much or it confirms the construction of the braces. Many of the patients return to Craig Rehabilitation Hospital as visitors or for re-evaluation and to Mr. Bruce Scott for their repairs; thus, I would favour the latter explanation from my contact with the patients for the past two years.

The 48 who 'would like' to be braced again correlates positively with questions 1 through 5. It would appear the message is getting across to 64 per cent. of the patients who received questionnaires and to 92 per cent. of those who answered.

Comparison with other braces was asked for in essay form. The most general comments were: 'easy to don and doff, stand without other support, Bale locks, and hadn't seen any other type braces'.

Summary

The patient cannot see and probably could care less what goes into the solid shoe-ankle component. From his standpoint it would seem the main advantage of the braces is their simple design. I repeat, the patients have to wear them before they can appreciate their ease of use. I wish I had a control group of paraplegics with floppy ankle bracing only, to answer the foregoing questionnaire, as it is difficult to equate the bias of the answers due to the patients wanting to please their 'alma mater' and say the right things. My impression is that the brace used at Craig Rehabilitation Hospital has many advantages over other types. It appears, the proof is in the pudding, as evidenced by the response to the questionnaire.

Zusammenfassung

Der Patient kann nicht sehen und wahrscheinlich kümmert sich auch nicht was in seiner festen Schuh-Fussgelenk Komponente vorgeht. Der Hauptvorteil für ihn ist die einfache Konstruktion seiner Stützapparate. Ich wiederhole, die Patienten müssen sie tragen bevor sie die Leichtigkeit ihres Gebrauches richtig einschätzen können. Ich habe den Eindruck, dass die Fussstütze des Craig Rehabilitations Zentrum viele Vorteile gegenüber anderen hat, was auch aus der Beantwortung des Fragebogens hervorgeht.

Résumé

Description d'un nouvel appareillage pour paraplégiques conçu au Craig Rehabilitation hospital.

Un questionnaire a été distribué aux paraplégiques afin d'obtenir leur opinion.

Acknowledgments. My thanks to Dr. Jackson, Dr. Young, Miss Pat Rogge, Mr. Bruce Scott, who developed the brace and for their critique of this paper and to Mrs. V. Griffin and Mrs. Maurine Richards for their secretarial help.

A Super 8 mm. movie of gait training is available on loan from Craig Rehabilitation Hospital, 1599 Ingalls Street, Denver, Colorado 80214.