Constant Tension Springs on Long Leg Braces to Assist the Quadriceps Femoris

HAROLD M. STERLING, M.D., Brighton, Mass.
and
FREDERIC J. KOTTKE, M.D., Minneapolis

Patients with weakness or paralysis of the extensors of the knee, especially when this is associated with weakness or paralysis of the hip extensors, have great difficulty standing and walking. Many devices have been designed to support the knees, ranging from simple gutter splints, plaster splints, and nonjointed bars to jointed knee braces with knee locks. Ambulation with a stiff knee is difficult for a person who has normal strength and is a great problem for a person with paresis or other disabilities. For this reason many attempts have been made to design a brace which allows flexion during sitting and flexion and support during walking. A knee joint allowing 2 to 4 degrees of extension beyond 180 degrees offers fairly good support to the patient with moderate weakness in both hip and knee when he is standing or walking, but it requires active muscular force, either in the knee extensors, themselves or in the hip extensors, to extend the knee.

Where there is weakness of somewhat greater degree in both of these groups of muscles, such a brace becomes less satisfactory, and the patient often resorts to using the mechanical knee lock on the brace to obtain stability. More than 50 years ago mechanical knee extensors in the form of rubber bands or springs appeared, but they have been of limited use [1] because the contractile force of rubber bands and coil springs diminishes linearly with shortening, so that at full extension of the knee (the point at which the patient would like maximum extensor force) these devices offer their least resistance to flexion. If the tension is increased at full extension, the patient becomes unable to flex his knee.[2]

Prosthetic equipment research [3] has recently turned attention to the use of constant-tension springs [4] in many devices.[5] This report concerns the design and manufacture of long leg braces with constant-tension knee-extension supports for patients who are unable to stand and walk because their quadriceps are too weak when the knees are extended.

Construction

The brace itself (fig. 1) is a light double-bar long leg brace with high and low thigh bands and a high calf band. The ankle joint is prescribed to compensate for the disability of the specific extremity. In several of our cases a freely moving ankle joint with no stops or springs was adequate. In others, posterior stops or dorsiflexor springs were necessary because of weakness of the dorsiflexors of the ankle. The knee joint is a freely mov-

*Reprinted by permission from the *Journal of the American Medical Association*, Vol. 172, No. 12.

From the Department of Physical Medicine and Rehabilitation, University of Minnesota Medical School.

Read before the Section on Physical Medicine at the 108th Annual Meeting of the American Medical Association, Atlantic City, June 11, 1959.

ing nonlocking joint, allowing extension to about 183 degrees. Both thigh bars are extended 2 to 3 in. below the knee joint. A constant-tension spring is mounted on a ball-bearing pulley at the end of each extension arm, and the end of the spring is attached to the bar of the lower leg section to provide a constant tension extending the knee joint. It is necessary to keep the extension arm of the brace as short as possible, since the projecting points will limit flexion inside a trouser leg and may damage clothing.

The strength of the springs to be used can be estimated easily by applying a scale or strain gauge [6] to the brace at the proposed point of attachment of the springs and noting the force necessary to extend the lower leg with its brace and shoe when the patient is seated. When the patient has some strength in his knee extensors, he should assist in this process, thus lowering the necessary spring strength. A spring which can exert one-half of the necessary force is mounted on the freely moving pulley on each of the extension arms (fig. 2). The knee joint of the brace is centered at the center of flexion of the knee but lies posterior to the line of the thigh bar and its extension arm so that the knee joint can extend slightly beyond 180 degrees.

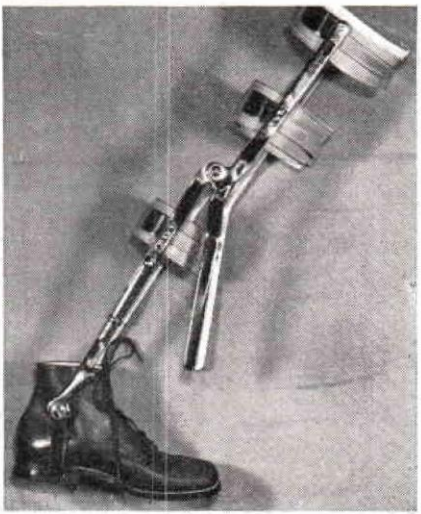

Fig. 1.—Brace before attachment of springs.

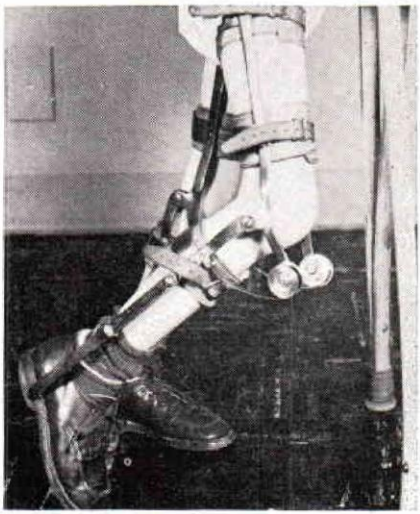

Fig 2.—Brace completed.

Report of Cases

CASE 1.—A 6-year-old boy with moderately severe general weakness due to amyotonia congenita was able to walk five or six steps without braces with Kenny sticks. He was fitted with lightweight long leg braces with spring-extension knee joints in December, 1957. He found that he could stand and balance immediately. Within one month he was able to walk with a 4-point gait and to walk up and down small stairs unassisted, with the braces and Kenny sticks. For the past six months he has been able to walk using sticks, but no braces, and attend public school. His gait continues to improve.

CASE 2.—Another 6-year-old boy had extreme weakness of the left leg as a result of having poliomyelitis in the fall of 1957. He was originally fitted with a long leg brace with a drop lock, but he was unable to walk with the knee unlocked in spite of several months of physical therapy and

gait training. In July, 1958, he was fitted with a brace with spring knee extensors. By January, 1959, he was able to walk quite well without the brace and, at the time of this writing, walks with an almost normal gait without the brace or sticks.

CASE 3.—A 60-year-old man with weakness due to compression of the spinal cord at L-3 and L-4, with weak hip extensors, no quadriceps action on the right, and fairly good action on the left, was fitted with two long leg braces with knee extensors in November, 1957, and was able to walk 60 ft. using a 4-point gait in December. Because he has not become stronger, he has continued to use the braces but can walk without assistance.

CASE 4.—A 3-year-old child with nonprogressive muscular atrophy which caused general weakness, most marked in the hip and knee, was unable to stand or walk without support. He was able to walk 100 ft. with gutter splints[7] and Kenny sticks.[8] In May, 1958, he was fittted with two long leg braces with knee extensors. He was able to walk with knee flexion and extension almost immediately after the braces were applied and now walks without assistance, using Kenny sticks for a swing-to and a 4-point gait.[9]

Two other patients have been fitted with similar braces too recently for a progress report.

Summary and Conclusions

A brace with constant tension throughout the range of knee motion has been described. Proper tension allows the quadriceps to participate in walking where residual strength is present, and thus the muscle can become stronger through use. Patients require less hip-hiking (elevating the pelvis on the affected side as the leg is swung forward) for walking and walk with a more normal gait. The freely flexed or extended knee joint offers greater ease in sitting and standing. In two patients, ambulation with braces developed quite rapidly and the braces were soon discarded, although both had had unsuccessful gait training directed at independent ambulation previously. Two patients continue to use these braces because of persistent weakness.

References

1. (a) Schanz, A.: Handbuch der orthopadischen Technik fur Aerzte und Bandagisten, Jena, VEB Gustav Fischer Verlag, 1908, pp. 487-494. (b) Riordan, D. C., and Miller, M. E.: Bracing for Gluteus Maximus and Hamstring Paralysis, Phys. Therapy Rev. **34**:235-237 (May) 1954. (c) Terhune, S. R.: Apparatus for Correction of Flexion Deformity of Knee, J. Bone & Joint Surg. **30-A**:244 (Jan.) 1948.

2. Dollfus, P. H.; Lund, T.; and Lygind, F.: Elastic Splints for Patients with Paralysis of Lower Extremities, Arch. Phys. Med. **36**:564-566 (Sept.) 1955.

3. Muscular Rehabilitation Devices, in Engineering Department Data Book, Lansdale, Pa., Hunter Spring Company, sec. 70, p. 165.

4. Preliminary Design Data; Extension Springs, bull. 310 E., Lansdale, Pa., Hunter Spring Company.

5. von Werssowetz, O. F.; Elliott, R. M.; Riess, B.; and Witt, R. N.: Supportive Appliances in Rehabilitation of Paralytic Hand, Arch. Phys. Med. **36**:559-563 (Sept.) 1955.

6. (a) Force Indicators, bull. 310 N. Lansdale, Pa., Hunter Spring Company, p. 15. (b) Bull 750 C, Lansdale, Pa., Hunter Spring Company.

7. Doman, R. J., and Doman, G. J.: Useful Aid in Early Paraplegia Training, Phys. Therapy Rev. **36**:595-598 (Sept.) 1956.

8. Hoberman, M.: Crutch and Cane Exercise, in Therapeutic Exercies, edited by S. Licht New Haven, Elizabeth Licht, 1958, pp. 351-352.

9. Cicenia, E. F., and Hoberman, M. F.: Crutch Management Drills, Mod. Med. **26**:86-95 (Oct. 1) 1958.