

A Mobility System for Adult Paraplegics

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ABSTRACT

For many paraplegics, standing upright offers numerous medical, psychological, and functional advantages. Conventional long-leg braces represent one way to attain this goal, but the need for crutches to maintain balance negates much of the functional gain.

This paper describes a system for improving the mobility and functional capability of adult paraplegics: The PACO (Pivot Ambulating Crutchless Orthosis) allows a paraplegic to rise unaided from a modified wheelchair to a standing position in which both hands are free. Patient-powered pivot ambulation in the standing posture is another feature of this system, as is the capability to sit back into the wheelchair unaided. The PACO unit is compatible with the wheelchair; both are considered vital parts of the mobility system.

Introduction

For many paraplegics, standing upright offers numerous medical, psychological and functional advantages. Medical advantages include alleviation of decubitus ulcers, improvement of urinary and circulatory dysfunctions, arrest of calcium depletion from bones (osteoporosis), prevention of muscle contractions and heterotropic ossifications.

Psychologically, the ability to interact with others on their own level, rather than constantly being forced to literally look up to them, is a tremendous incentive to leave the wheelchair. And, the functional benefits of being upright are numerous, stemming from the fact that a large proportion of our physical environment is designed for the able-bodied. Although architectural barriers to buildings are rapidly diminishing, things such as wall telephones, clothes closets, book and display shelves, filing cabinets, kitchen cupboards and counters of all types make the interiors of most buildings inaccessible from a functional viewpoint. Job opportunities, also, are limited to seated positions.

The blocking of access to a room because of excessive narrowness of door passages is another serious functional problem. To architects, homeowners and buyers alike, the presence or absence of ceramic wall tiles in a bathroom seems of much greater importance than the use of bathroom doors of adequate width. It is amazing how many high-priced homes have bathroom doors four, six or more inches narrower than any other interior door in a home. There is no excuse for such lack of consideration for the wheelchair-bound, and it is not surprising that they feel discriminated against.

The significance of this research lies in the truly useful improvement in a paraplegic's accessibility, mobility and ability to function.

The PACO Concept

It is probably safe to say that most paraplegics who graduate from bed to wheelchair have also a strong desire to advance further. To deal with others again "on their eye level" becomes a powerful enough incentive for considerable exertion toward mastering ambulation; all wheelchair-bound paraplegics appear quite sensitive about their psychologically unpleasant need "to look up" to practically everyone else all the time. The sum total of such psychological and other medical factors matters enough to become a strong incentive to those of great enough physical and spiritual strength as they persevere toward getting back on their feet.

Not all paraplegics can build up enough persistence and upper body muscular strength to successfully learn how to walk on crutches wearing long-leg braces. Many who try don't achieve it until years have passed after spinal cord injury. Somewhat tragically, all these investments by many people in many ways usually end up to be an exercise in futility. Not surprisingly, those paraplegics who succeed, like other people, become eventually tired of doing things the hard way, and most paraplegics eventually revert to full time use of the wheelchair.

It is for this reason that this research focuses on methods that:

- (1) Are quickly and easily learned,
- (2) Are easy to use without undue exertion,
- (3) Leave the hands free and available to do something worthwhile while standing.

These new techniques can eventually help more adult paraplegics to graduate from the wheelchair. Perhaps more importantly, it will entice them to stay on their legs because of the greater ease in using these new methods and an apparent feeling of greater safety.

In order to accomplish these goals, PACO, an acronym for "Pivot Ambulating Crutchless Orthosis", was designed to be one component of a complete mobility system for adult paraplegics. Pivot ambulation accomplishes forward locomotion through successive body rotations about vertical axes lateral to the feet (Figure 1). The related swivel walking utilizes basically the same concept, with the soles of the feet as the respective points of rotation. In either case, the amount of forward progression with each step is a function of the lateral spacing between pivots and the angle of rotation. Similar methods of locomotion have also been described by Spielrein (1), Barry et al (2), Rose and Henshaw (3-7), and Glancy(8),

For short distances (50M), the PACO unit provides mobility and upright support. To travel up to one kilometer, a conventional wheelchair is an efficient, practical solution, while longer trips would necessitate a motorized vehicle (automobile or bus). The goals of the PACO system are:

- 1.) Support and balance in an upright position without use of hands.
- 2.) Limited ambulation in the upright position.
- 3.) Unaided standing and sitting.
- 4.) Compatibility with wheelchairs.
- 5.) Easy to don and doff.
- 6.) Easily adjusted by an orthotist for various patients.

The PACO concept was inspired by the 1970 development of the "Parapodium" for children at the Ontario Crippled Children's Centre by Wallace Motloch (9-14). Crutchless standing became a reality for adult paraplegics in the fall of 1971 with the development of PACO I (15). After adding a pivot walker attachment, a 6'2" (188cm) adult male paraplegic became the first paraplegic to ambulate in PACO II (Fig. 2) without the use of crutches. A distance of 80 feet (24.4M) was attained in 210 seconds. PACO II met the primary design goals listed above, but did not allow unaided standing or sitting because the knees had to be locked in full extension prior to use. It also was not adjustable to accommodate a general population.

Present State of Effort

PACO III was designed to retain the advantages of previous units while satisfying all of the stated design goals. The first step toward independent standing was the design of wheelchair arm rests which can be turned around to that they project forward of the chair. Telescoping tubes are then lowered to the floor to prevent tipping forward, and the arm rests are raised up as much as 40cm. The result is a pair of stable parallel bars attached to the wheelchair (Fig. 3).

Like its predecessor, PACO III (Fig. 4) has upper and lower modules for easier donning and doffing while seated in the wheelchair. The lower module is in essence a triangular structure. Telescoping tubes allow adjustment for knee to ankle length. Knee locks on the upper module slide onto the hex studs located at the knees of the lower module, much like a socket wrench onto a nut. The knee locks employ a cable-wrapped capstan which, when engaged, allow knee extension but not flexion. When standing, therefore, the knee locks will hold the paraplegic's weight if he/she cannot do so with his/

her arms. When fully upright, preset latches at the knees and hips automatically engage, creating a rigid structure from base to torso support. To sit, the hip and knee latches are disengaged, and the capstan can be gradually slipped with the lock levers to allow controlled descent.

Thin-wall rectangular aluminum tubing forms the lateral struts of the upper module, representing a five-fold increase in lateral bending stiffness over the solid I-section of PACO II, and an 18% saving in weight. Also, the mechanisms which actuate the hip and knee locks are contained within the tubing, making the design cleaner and more reliable. Adjustability of the upper struts (knee to hip length) is accomplished simply by sawing the tubing to length and drilling four holes.

Limited trials of PACO III with an inexperienced paraplegic were undertaken in May, 1978. He rapidly mastered crutchless standing and pivot walking, and was very enthusiastic about the concept. Certain design weaknesses in the capstan knee locks were also discovered; redesign of that portion of the PACO system is presently in progress.

The main disadvantage apparent in this concept at present is relatively poor cosmesis. It is our hope that this will be offset by the advantages, especially for active paraplegics. Evaluation of future PACO units currently under construction should help clarify this question.

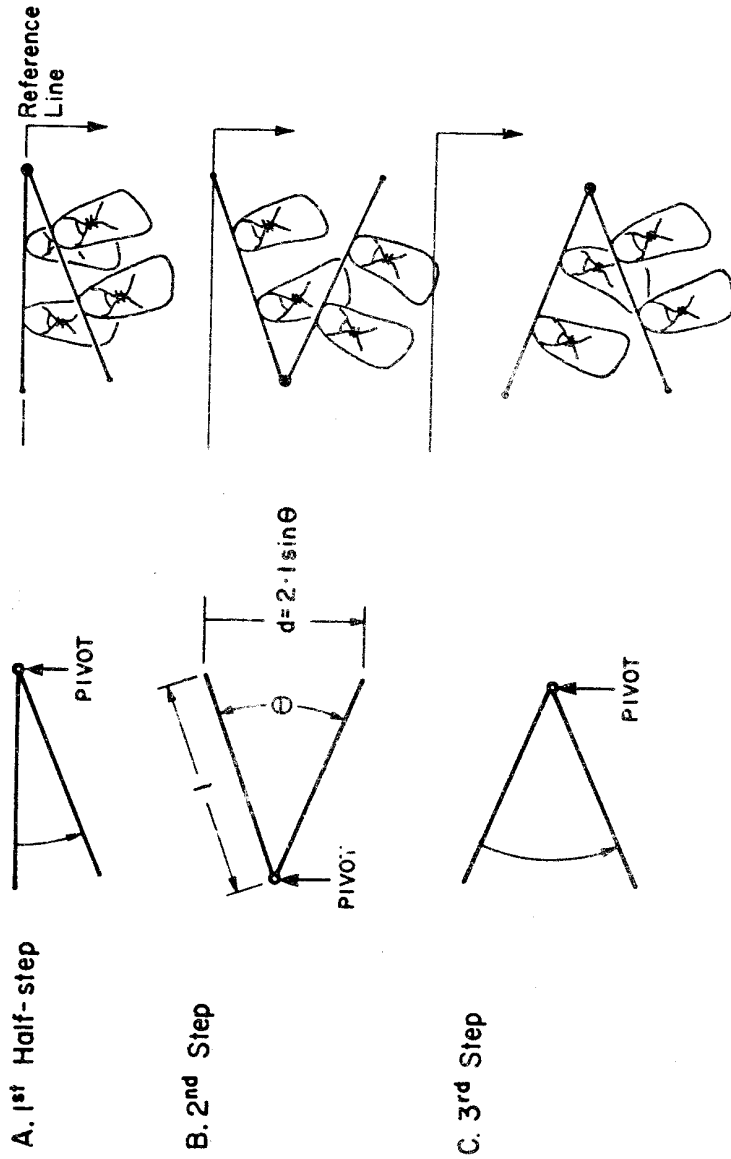
Conclusion

The PACO concept is a mobility system for adult paraplegics that incorporates a wheelchair for long distance travel and an orthosis that provides crutchless support for standing and short range pivot ambulation. Modified wheelchair armrests convert to parallel bars to facilitate transition between sitting and standing. The complete system provides a method to capitalize on the medical, psychological and functional advantages of standing upright.

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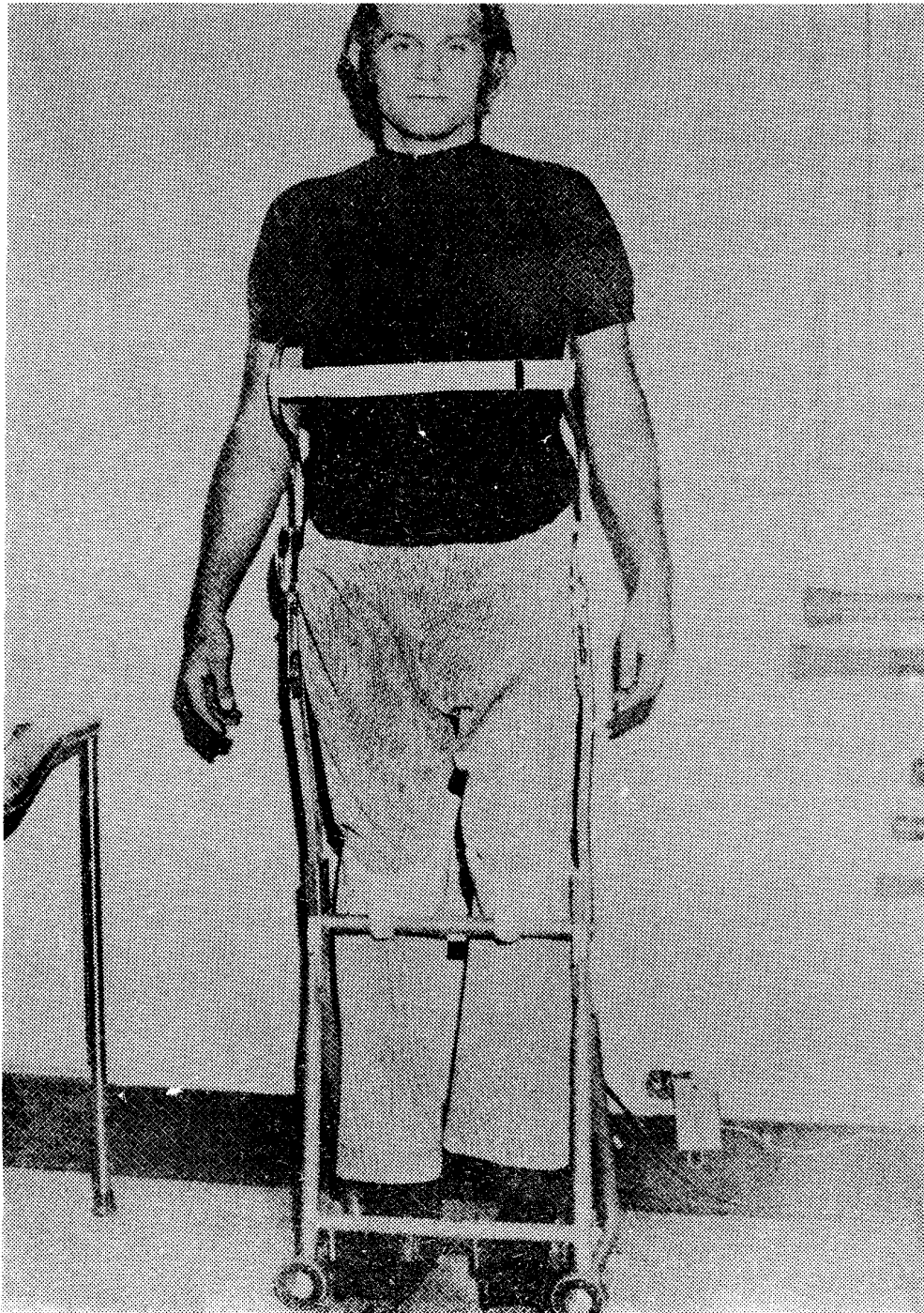
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Pivot ambulation - forward progression by alternating rotations about two lateral pivots.

Fig. 1 Pivot ambulation - forward progression by alternating rotations about two lateral pivots.



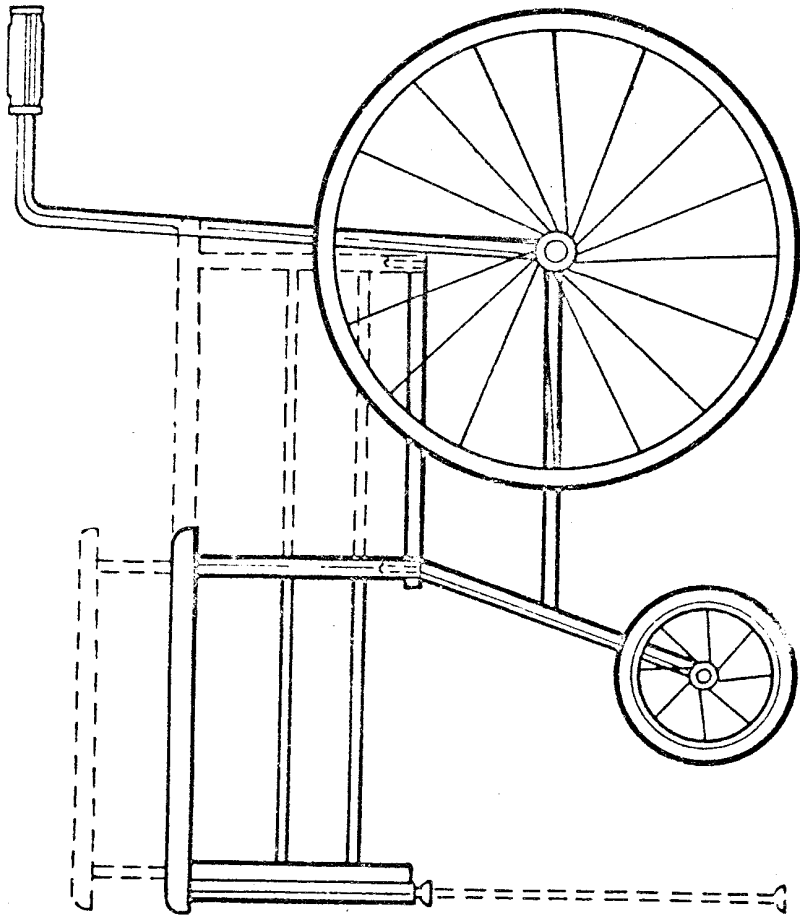


Fig. 3 Modification of wheelchair arm rests as parallel bars to aid in standing.

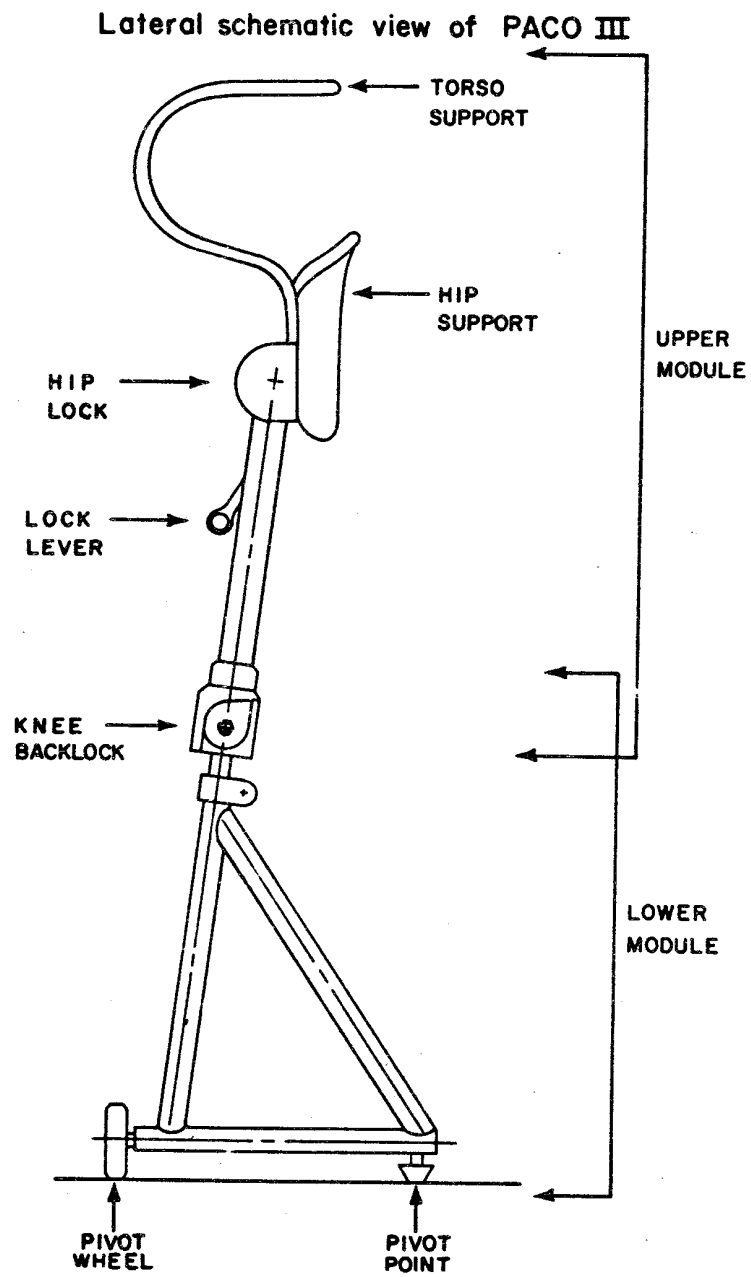


Fig. 4 Lateral schematic view of PACO III.