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The potential for ambulation by severely handicapped cerebral palsy patients

J. STALLARD, R. E. MAJOR and S. E. FARMER

Orthotic Research and Locomotor Assessment Unit (ORLAU), The Robert Jones and Agnes Hunt Orthopaedic and District Hospital, Oswestry, UK.

Abstract

Whereas walking for paraplegic patients is now a routine clinical option, ambulation for heavily handicapped cerebral palsy patients is less well established. There are good reasons for supposing that therapeutic benefits similar to that achieved with paraplegic patients are possible for this group. However, the biomechanical problems which must be overcome are different and in many ways more difficult to address.

The most important factors are identified as appropriate truncal support, control of abduction/adduction, rotation and flexion range at the hip, and of knee flexion.

A means of applying these controls is described as being a combination of a walking frame and orthosis. The special walking frame provides adjustable support at thoracic, abdominal and sacral levels and incorporates castor steering and upper limb support. Controls on lower limb movements are applied through a special orthosis which has a readily available variation of specification to accommodate the wide range of conditions met in cerebral palsy.

Practical application of a prototype system has shown that it can enable patients to walk unaided. However, in most cases it was used indoors only.

Evaluation of the experience in applying the system has enabled the fundamental principles to permit more practical applications to be defined.

All correspondence to be addressed to John Stallard, Technical Director, ORLAU, The Robert Jones and Agnes Hunt Orthopaedic and District Hospital NHS Trust, Oswestry, Shropshire, SY10 7AG, UK.

Introduction

Walking for paraplegic patients is now a routine clinical option which is widely adopted (Douglas *et al.*, 1983; Motloch, 1980; Kirtley, 1992; Lissons, 1992; Butler and Major, 1987). None of the systems described has sought to address the problem of providing walking for total body involved cerebral palsy patients. There are good reasons for this in that lack of control in the upper limbs and trunk creates a different challenge of patient stabilisation. In the lower limbs there is also a different biomechanical situation with the potential for harnessing the available active motor power, despite the inherent lack of motor control.

The objectives of walking for paraplegic patients have been widely proposed as (Rose, 1983; Menelaus, 1987):

therapeutic benefit;

improvement of independence.

Confirmation that these objectives can be met in high lesion spina bifida patients has been reported by Mazur *et al.* (1989) who showed not only that non-walkers had five times the number of pressure sores and twice the number of bone fractures, but also that paediatric patients who walk are more than three times more likely to be able to move around the community independently. The success of properly controlled clinical provision of ambulation to spina bifida patients suggests that the benefits can be reproduced for other clinical groups.

Whereas many congenital or neonatal pathologies have been decreasing, cerebral palsy has remained stubbornly consistent at 3.5 per 1000 live births (Pharaoh *et al.*, 1990). Since survival rates of cerebral palsy patients

are now increasing sharply (Alberman and Botting, 1991) ever increasing numbers of those who are severely handicapped are presenting at orthopaedic clinics. There is often an ambition of patient, parent and/or carer for walking to be achieved and the experience with spina bifida patients reported by Mazur *et al.* (1989) indicates that there is therapeutic benefit in such activity. Innovative solutions are necessary for the stability requirements of the total body involved cerebral palsy patient and the harnessing of the active power available in their lower limbs. However, if successful walking systems can be developed for this group they could bring about important benefits, and there is clear justification for a fundamental examination of the problems which need to be addressed. Early attempts (ORLAU, 1979) centred on simple modifications of paraplegic walking orthoses. Whilst these achieved limited success they also highlighted significant differences which demanded more in-depth examination. Empirical development gradually led to a more detailed understanding of the requirements of ambulation for severely handicapped cerebral palsy patients (ORLAU, 1982, 1984 and 1987; Thompson and Patrick, 1990). Further consideration of the empirical experience has enabled some basic principles to be established, and these can lead to further improvements in the future.

The biomechanical problem

Whereas the biomechanics of providing ambulation for the paraplegic patient are clearly definable (Stallard *et al.*, 1986) the requirements for stabilisation and propultion in total body involved ataxic or athetoid cerebral palsy patients are much less clear cut. A further complication is the variability of the condition, which is in contrast to the paraplegic patient where the only variabilities are level of lesion, patient shape, available joint ranges and upper limb strength and co-ordination. Nevertheless careful observation of athetoid and ataxic patients shows that there is sufficient commonality in the condition to premit some basic design criteria to be established.

Aberrant movements in the upper limbs make them a poor source of propulsive input. Overlying this is a lack of truncal control which means that the trunk cannot be relied upon to provide a stable platform from which to control the available active power in the lower limbs. The lower limbs also have poor voluntary control, though they are generally capable of generating powerful torques about all of the joints. This means that they are unable to provide the necessary internal stabilisation to prevent collapse of the skeletal structure when standing nor produce controlled propulsive forces.

If a patient is given the necessary truncal support to prevent collapse a variety of aberrant movements in the lower limbs may be observed which would require external control to permit an appropriately patterned reciprocal walking action:

(i) abduction/adduction;
(ii) internal/external rotation about the hip joint;
(iii) intermittent excessive hip flexion;
(iv) intermittent knee flexion.

It would appear to be rare for all of these requirements to be present in all patients. Therein lies the major aspect of the variability and this is compounded by the severity and frequency of the aberrations.

Orthotic solutions

The fundamental biomechanical problems which need to be addressed were observed during experimental provision of orthoses and walking frames in previous studies of cerebral palsy patients (ORLAU, 1987; Thompson and Patrick, 1990). It became apparent that two primary elements are required:

(i) a walking frame which provides appropriate truncal alignment and support;
(ii) a hip-knee-ankle-foot orthosis (HKAFO) which resists and controls the aberrant hip adduction, abduction and rotation, and limits hip and knee flexion and extension ranges.

A walking frame requires to give both sagittal and coronal truncal support and additionally may need to give sagittal support, anteriorly and posteriorly, at the sacral level. The ORLAU Walking Frame (Thompson and Patrick, 1990) (Fig. 1) was designed to provide all of these elements of support combined with a handle to support the arms and provide a means of pushing for forward progression of the frame. Each element is adjustable to accommodate individual patients. It has four wheels and permits an option of castored or

Fig. 1. The ORLAU Walking Frame.

non-castored steering action on the front wheels. The aberrant movements of the cerebral palsy patient to cause significant stability problems. To counter these, low level weights are an option commonly used to enhance the Walking Frame stability. Whilst the Walking Frame was designed as part of an experimental cerebral palsy walking system it has been widely used in other applications where the range of options has proved attractive.

Controlling the aberrant movements of the lower limbs requires an orthosis which crosses the hip joint, knee joint and then ankle joint (HKAFO). Crossing the knee and ankle joint is necessary not only to permit control of those joints but also to ensure there is adequate resistance to the rotational movements of the hip joint. This control is most important since the conflicts between the two limbs arise not only through bilateral hip abduction but also through swing leg hip rotation combined with knee flexion. Experience has shown that the use of a simple thigh cuff in cases where knee and ankle control are not considered necessary is inadequate as the limb is able to rotate within it.

Since the orthosis is theoretically required merely to resist uncontrolled movements it was initially considered that a lightweight structure would suffice. Comparisons with the supportive requirements of the ParaWalker orthosis (Butler and Major, 1987), which is intended to provide walking for thoracic lesion paraplegic patients, initially reinforced the view of lower structural demands necessary in a controlling orthosis. It was recognised there was a need to proceed in an empirical manner, as it would not be possible to measure the aberrant torques during walking without providing the orthotic resistance to these. In the event experience showed, with a number of patients, that the aberrant abductor/adductor torques generated were of the same order of magnitude as those required to provide lateral hip joint support in paraplegic walking devices. An evolutionary approach demonstrated with patients who had progressed beyond the infant stage that structural rigidity rivalling that achieved in the ParaWalker would be necessary to counter the lower limb scissoring which is such an ubiquitous effect in the target group of patients.

The improvement which a control orthosis can provide was observed in a number of early patients. This qualitative impression was reinforced in one patient by monitoring the change in relative energy cost between the patient using the walking frame only and the control orthosis together with the walking frame. Physiological cost index (PCI) was used, in which heart rate and speed are combined to give a reading of heart beats per metre (MacGregor, 1981; Butler *et al.*, 1984). A standard test of five walks of six metres with one minute rest between each was used (Nene and Jennings, 1992) and the result was:

walking frame only	3.8 beats/metre
walking frame and control orthosis combined	1.8 beats/metre

It can be seen that there was a 52% reduction in PCI (2 beats/metre). When placed in the context of paraplegic walking in the ParaWalker (average 3.82 beats/metre) or RGO (average 5.34 beats/metre) (Bowker *et al.*, 1992) there is an indication of the potential practicality of walking for cerebral palsy patients in combined walking frame and control orthosis systems.

Variability of biomechanical specifications

The variability of the detailed biomechanical problems is also an issue which requires to be addressed. Common differences in the required control at hips and knees were found to be:

(i) hip flexion range;
(ii) fixed standing position at the hip;
(iii) knee flexion range;
(iv) knee extension assist.

Until walking has commenced it is usually not possible to identify whether or not these controls are appropriate and ideally an orthosis needs to permit options to be selected during the patient training phase of treatment.

As a result of progressive empirical experience a design specification for a variable specification orthosis (VSO) has been evolved within ORLAU. This is based on the structure of the ParaWalker but incorporates the following variable joint control features:

(i) *Hip joint*
A free or limited range of hip flexion and extension is incorporated. (This can be adjusted to permit a standing stop but then the flexion/extension adjustment is removed). Sitting override is provided in all cases. An optional extra component is available to permit both standing stop and limited hip flexion/extension range.

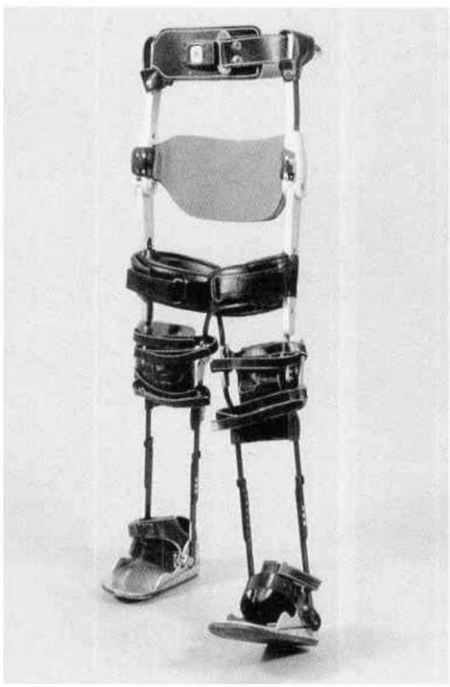

Fig. 2. The ORLAU Variable Specification Orthosis.

(ii) *Knee joint*
A free or limited knee flexion range with knee extension assist as an optional extra feature.

(iii) *Hip and knee joint alignment*
Adjustments to the distance between the hip and knee joint provided to ensure that the anatomical and orthotic joints can be maintained in alignment as the patient grows.

(iv) *Ankle joint*
Fixed with shoe plate enabling standard shoes to be used. Additional coronal plane ankle controls available as optional extras. Quick release attachments to knee-ankle-foot orthosis (KAFO) side members for conventional polypropylene ankle-foot orthosis (AFO) available as an option. (Farmer *et al.*, 1993).

Figure 2 shows the ORLAU Variable Specification Orthosis. Its generic similarities to the ParaWalker will be apparent. However, though there are visually common features, specifically with regard to the structural design, there are important and significant differences in their control functions which renders them non-interchangeable.

Treatment system

As with ORLAU ParaWalker (Butler and Major, 1987) it has become obvious that a walking system for severely handicapped patients will require an overall treatment approach if it is to be successfully and appropriately applied. Each patient will require careful orthopaedic and physiotherapy assessment. When a decision to proceed is taken there is a requirement for very accurate patient measurement with particular attention being paid to alignment of anatomical and orthotic joints. When delivered the orthosis requires careful fitting to promote the best possible comfort and function and reduce the risk of tissue damage, and the walking frame needs to be set up to accommodate the particular requirements of the individual. Training the patient also includes optimising the system specification and advising parents, carers and physiotherapists etc.

Once the training phase is successfully completed there is a need for regular on-going assessment at approximately six month intervals.

Treatment outcomes

Fourteen patients have been treated in the prototype ORLAU Locomotive Guidance System. Walking was generally restricted to indoor use but the majority of patients were able to walk with only limited supervision. In many cases physiotherapists were able to allow patients to move at will within the confines of the Special School. Some patients used the system at home and there were reports in a few cases of the child assisting with simple chores, such as laying the table.

Commonly patients and parents found the system worthwhile even though the distances walked were relatively small, as might be expected in the environment of home or school. Regular clinical reviews revealed that patients did generally continue to use the system over a period of years, the motivation expressed by parents being that it broadened the scope of activity and improved the outlook of their child. As they got older some of the patients gave up ambulating because it became too inconvenient. However, eight are still using the system and five of these have been doing so for more than five years.

Quite commonly patients used the orthosis for activities other than walking. The additional stability which it provides during sitting permitted some children to concentrate on upper limb activities so that they were able to accomplish particular tasks more speedily. Using the orthosis as a standing device with the hips locked, together with an additional stabilising device (ORLAU, 1990 and 1985), enabled some patients to undertake activities alongside their peers in the school environment.

In a small number of cases patients improved their overall motor control over an extended period during which they were regular users of the system. One child developed an ability to stand independently and then later still take a few steps. A different child was, again after several years' use, able to walk using the walking frame without the orthosis. Clearly it is not possible to ascribe such improvements specifically to the system. However, applying appropriate biomechanics through orthotic intervention has in lower levels of handicap in cerebral palsy patients led to motor learning (Butler and Major, 1992; Butler *et al.*, 1992; Major and Butler, 1995). This would suggest that the improved motor control achieved with some patients could be attributable to the Locomotor Guidance System. At the very least it demonstrates that such walking activity does not interfere with acquisition of motor skills.

Discussion

The results achieved with the experimental ORLAU Locomotor Guidance System have been greatly encouraging with the majority of patients who have had the opportunity to use it. However, its use has raised as many questions as it has provided answers to the dilemma of providing walking for an extremely handicapped group.

Careful analysis of the walking patterns adopted by the majority of the patients involved in the trials revealed a number of factors which need to be investigated if the system is to become both more widely applicable and of greater utility to the patients and their families.

An upright truncal posture during walking is an important requirement if appropriate walking patterns are to be stimulated and social interchange during walking is to be promoted. Observation of patients walking in the ORLAU system also revealed that patients require some vertical support if reciprocal lower limb patterning is to be promoted.

Some patients were clearly frustated by the need for their arms to be constrained to operate the walking frame, and steering the system by this method was in many cases an uncomfortable compromise.

It was observed that getting the patient into the complete system of orthosis, then the Walking Frame, was a time consuming and inconvenient activity which made great demands on carers. As the children became older (beyond 8 years) it was not uncommon for three carers to be required for this to be achieved safely.

It has become clear that the existing ORLAU Locomotor Guidance System has successfully addressed the orthotic demands of walking for the heavily handicapped cerebral palsy patient. The structural requirements were found to be much more demanding in the over 8 year old group than had been anticipated. Substantial orthosis strength and stiffness is an essential requirement to ensure both utility and reliability of the system, as is the range of variable options for control because of wide differences in patient motor impairment.

In examining the deficiencies of the walking frame for the target group a review of options was undertaken. Other approaches to walking frames were identified and in particular rear support systems as initially promoted by Motloch (Motloch, 1980; Bleck, 1987) and taken up later by Hart (1990) were seen as potentially suitable arrangements. Superficial examination of these suggests that in their existing form they would not provide sufficiently controlled vertical support or structural rigidity to accommodate the larger patients using the existing ORLAU Walking Frame. It was also clear that transfer of heavy patients into this type of walking frame would be potentially more difficult than with the existing system.

Much encouragement is taken from the results so far achieved. However, further work is now to be undertaken so that the problems of wider practicality can be addressed.

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