Functional standing for paraplegics: is it a sensible goal?

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Abstract

In a FES standing project, we screened 522 complete paraplegics for functional standing. Although 115 (22%) met our selection criteria according to their records, only 15 progressed to safe and independent standing and 7 continued to do so at home. We estimate that about 10% of the complete paraplegic population are suitable for FES functional standing. More emphasis should be placed on therapeutic standing to help the other 90% and to try and increase the number available for functional standing.

Introduction

In 1991, we planned a project to investigate the use of lumbar motor root stimulator for the restoration of leg function in complete paraplegics. The LARSI project (Lumbar Anterior Root Stimulator Implant) ran from 1992-2001. The main purpose that we envisaged for the device was standing in front of a wheelchair which had extending handles, as part of the activities of daily living. This was described by Kralj and Bajd [1, p114] and we called it *functional standing*. The volunteer subjects had to choose to have a device chronically implanted without being able to confidently anticipate its functional value. Clearly it was of the utmost importance that the individuals were suitable in every way and were as fully informed as possible. Our selection process was therefore cautious and rigorously applied: it has been described by Rushton *et al*. [2]. One of the products of the project, is an estimate of how many complete paraplegics are suitable for functional standing. This paper summarises these findings. We also offer some opinions about desirable directions for progress in FES-standing.

Selection Procedure

The stages of the procedure, which are listed in Table 1, were:

- identifying patients who met the selection criteria (Table 2) by consulting records and talking to medical doctors;
- inviting patients to come and find out about the project;
- assessing those interested in the clinic;
- running a programme of progressive muscle training;
- standing the subjects in the clinic;
- letting them stand at home (using closed loop control [3]);
- offering an implant to suitable subjects.

The progressions between stages in this procedure depend either on objective physical facts or on the wishes of the subjects. The former are indicated in Table 1 by the fractions in the third column. By multiplying these fractions together, we can find the proportions of the whole population who we would expect to be physically able to reach this stage. In other words, this is an estimate that assumes that all paraplegics would wish to follow the procedure as far as they are physically able.

The selection criteria that were applied are shown in Table 2. Criteria 6-9 would not apply to all FES-standing projects and these make up 27% of the rejections. Consequently, if we want to reach a general (i.e. most optimistic) estimate of how many paraplegics are suitable for FES-standing, we assume that these would have gone forward, raising the proportion of suitable paraplegics from the 22% at Stage 2 in Table 1 to 43%.

Stage	Persons at each stage	Number	Fractions
0	Database records in two Spinal Injury Units (1982-1999)	1795	
1	Complete traumatic paraplegics	522	
2	Those who met the selection criteria	115	22% of 522
3	Those interested in joining the project	79	
4	Those judged to be suitable of those interested in joining	37*	47% of 79
5	Those who opted to join the project and started muscle training	28	
6	Those with sufficient muscle strength following training	18	
7	Those who demonstrated "safe and independent" standing in the clinic	15	54% of 28
8	Those who went on to stand at home	12	
9	Those who continued to use surface stimulation for standing at home	7	47% of 15
10	Those who opted for a LARSI implant	2	

Table 1. * Reasons for exclusions at this stage included: hip and ankle contractures; presence of syrinx; dislocated hip; evidence of dysreflexia; inadequate bone density; evidence of LMN lesions; or excessive spasticity.

	Criteria	Number	%	
1	Lower motor neuron paralysis	23	15	73 % not project-specific
2	Medical complications (including death)	37	24	
3	Contractures	30	20	
4	Mental state	17	11	
5	Excess spasticity	4	3	
6	Living too far away	3	2	27% project-specific
7	Age (16 < age < 65)	20	13	
8	Syringomyelia	8	5	
9	Spinal fixation	10	7	
	Total	152	100	100

Table 2. Reasons for the rejection of 152 patients according to our exclusion criteria. These are only some of those shown as rejected at Stage 2 in table 1 (taken from Rushton *et al*. [2]).

From the figures, the fraction of complete paraplegics who could become "safe and independent" standers, if they wanted, is $0.43 \times 0.47 \times 0.54 = 10.9\%$, similar to the "user population" of 10% identified by Jaeger *et al.* [4]. Given that these SIUs serve a population of about 10m and that the records were for new injuries over 17 years, we can see that the number of beneficiaries from FES-standing could only be about $522 \times 0.109 \div 10 \div 17 = 0.3$ persons per million per year.

Unfortunately, many of those who could stand decide that they do not want to; they dropped out between stages 2 and 3, or between stages 4 and 5. Even more disappointing is that less than half (47%) of those who showed that they could stand, continued to do so (i.e. progression from stage 7 to stage 9).

Improving Functional Standing

To make FES-standing an ADL, our plan was to use extending handles on wheelchairs as described by Nash *et al.* [5]. This was confounded by the appearance of a plethora of new wheelchair designs, and the reluctance of our subjects to use standard chairs with handles. This meant that those who progressed to standing could not stand from wheelchairs and therefore their standing was less functional. Thus, part of the reason why so many subjects stopped standing may have been the poor functional advantage.

Of course, improving upright function has long

been a research goal and there are many well-known ways to do this, such as:

- using implanted stimulators for better cosmesis, reliability and donning time;
- using orthoses to reduce quadriceps fatigue;
- using controllers for standing up and sitting down [6];
- using controllers for standing without upper-body support [7]; and
- FES-walking

However, we should bear in mind that, from these results, the ceiling on these improvements is a "user population" of only about 10% of paraplegics or about 3% of spinal cord injured people. These relatively small numbers may make it difficult to justify clinical bioengineering support for FES standing and for companies to produce the required equipment.

Therapeutic Standing

Those of our subjects who continue to stand at home probably persist because of its therapeutic benefit. Unfortunately, our selection process denied this possibility to about 90% of paraplegics (and all tetraplegics). If, instead of aiming for the function of independent standing, we aimed at therapeutic standing, we could relax the selection criteria so that a higher proportion is included. Perhaps some of the subjects would progress so much that they meet the criteria for functional standing.

The use of therapeutic stimulation sometimes relieves spasticity and may diminish contractures [1, page 130]. If all the patients who were rejected from our functional standing programme because of excessive contractures or spasticity had received therapeutic stimulation, and *if* this always relieved the condition, the proportion of all complete paraplegics to meet the criteria (Stage 2) would rise to 61% (from 22% in Table 1) - a great improvement.

A system for therapeutic standing need not be wheelchair-mounted. Consider, for example, the so-called *mechanical rotating frame* of Matjacic & Bajd [8]. Such a system can prevent falls; can be adjusted to accommodate joint contractures; and could be instrumented so that only appropriate stimulation is applied (e.g. waiting for spasms to pass). Perhaps the design could be developed so that, for example, actuators carry out stretching exercises under computer-control. What is probably of critical importance, if such methods are to be given a fair trial, is that imagination is used to make the therapeutic standing into a game so that it is not boring. What about table tennis (narrow table?) or pistol-shooting (the arcade game?). The patient should be challenged to develop new whole-body motor skills.

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