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# Gait recovery pattern of unilateral lower limb amputees during rehabilitation

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**Abstract**

The aim of this study was to determine the rate at which gait recovery as measured by temporal distance factors (velocity and symmetry) occurs in unilateral lower limb amputees. A microcomputer footswitch system was used to record the gait patterns of twenty subjects, mean age 65.1 years. The initial measurement was taken when the subject was capable of walking 6 metres with an interim prosthesis within the parallel bars. The patient sample as a whole was analyzed and subjects were further divided into four groups, depending on ambulatory aid required at discharge. Group A, n = 3 used no aid, Group B, n = 5 used a single stick, Group C, n = 6 used 2 single sticks and Group D, n = 5 required frames. A one way analysis of variance ($F = 4.55$, $p = 0.02$) showed a significant difference between the Groups, (A and D, B and D, C and D). The major velocity increase occurs within the first 30 days of the gait training programme. Overall about 55% increase in velocity can be expected within the first fifteen day period followed by an additional 30% between days 15-30. A moderately strong correlation ($r = 0.78$) was found between initial and discharge velocity. The correlation between initial and discharge symmetry was weaker ($r = 0.50$).

## Introduction

Clinical experience shows marked variation in the rate at which amputee patients gain proficiency in the use of a prosthesis. The younger nonvascular patient is generally perceived as attaining a better rehabilitation outcome as measured by walking speed, and energy costs than the older vascular patients (Perry and Waters, 1981). The older amputees with peripheral vascular disease represent the largest group within the amputee rehabilitation field and show considerable variation in their ability to master a prosthesis. Many of these patients die either during or soon after rehabilitation. Mortality rates for this group of subjects two years after amputation have been reported as being between 20% and 41.2% (Ebskov and Josephson, 1980; Kihn et al., 1972). The short life expectancy and typical poor health pattern of peripheral vascular disease amputees dictate that time spent in rehabilitation programmes must be carefully monitored.

Gait analysis is a useful objective method of evaluating amputee progress. Skinner and Effeney (1985) observed it should be particularly useful in monitoring the rate of rehabilitation. They went on to say that unfortunately the technique has enjoyed very limited application.

The authors could find no previous studies that examined the rate of gait recovery following amputation or indeed any studies suggesting optimum time periods for prosthetic gait training.

## Methods

### *Subjects*

The first twenty unilateral lower limb amputees admitted to Caulfield Hospital for prosthetic gait retraining after 1/9/87 were admitted to the study. Inclusion required that the recent amputation was a new level of amputation for that leg and that a prosthesis was never previously fitted for the purpose of walking at that level of amputation on that leg. There were no exclusions on age, level of amputation or cause of amputation.

Fifteen (75%) of the subjects were male. The mean age of the entire group was 65.1 years with a range of 25-88 years. Most amputations were as a result of peripheral vascular disease (80%), three from road trauma (15%) and one (5%) from cancer. The majority (75%) of the subjects were below-knee amputees, three (15%) above-knee, one (5%) through-knee and one (5%) hip disarticulation.

### *Procedure*

The study was conducted in a 401 bed rehabilitation and extended care hospital with a

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30 bed amputee and diabetic ward. The programme included pre-prosthetic training, fitting of an interim prosthesis by the prosthetic department, gait training by the physiotherapy department, general rehabilitation by a multidisciplinary team and definitive limb prescription. The study was conducted on both an in-patient and out-patient basis. There is a prosthetic by the prosthetic department on-site and once the patient had been fitted with an interim prosthesis and was capable of walking six metres within the parallel bars the first gait recording was taken. The patient's gait was then re-measured approximately twice weekly. Conditions which prevented the patient participating in the gait measurement sessions were recorded. These included skin breakdown, illness, condition of the remaining foot and other. The gait measurement was taken using the patient's current ambulatory aid.

### *Equipment*

A micro-computer footswitch system (Perry et al., 1981) was used to collect the temporal-distance parameters of gait. The system consists of insole footswitches, a photoelectric stop-start device, a recorder and a calculator. Each footswitch contains a cluster of contact closing sensors in the areas of the heel, the fifth and first metatarsal heads and the great toe. The recorder stores the elapsed time of the run and data from the footswitches for up to 20 studies. The calculator accepts the data stored by the recorder and calculates the gait parameters, printing the results on a permanent record.

## Results

Subjects were divided into 4 Groups depending on style of ambulation aid required at discharge. Group A, n = 3 used no aid, Group B, n = 5 used a single stick, Group C, n = 6 used two single sticks and Group D, n = 5 required a frame. Subject 20

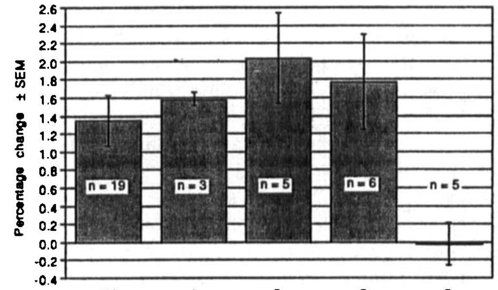


Fig. 1. Mean Percentage Change in Velocity per Day for all Subjects and each Group Over the Mean Period of 63.2 ± 5.9 Days

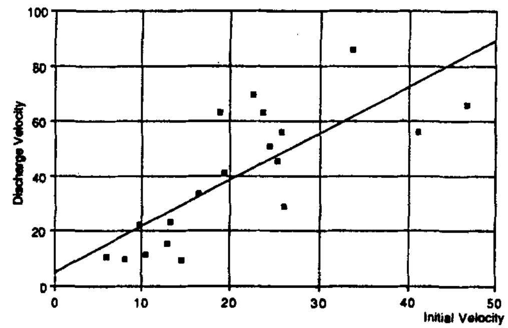


Fig. 2. Change in Velocity in all Subjects Over the Period of Gait Training

(Pearson Correlation r = 0.78)

was excluded from the analysis as he was discharged using a rollator. The mean percentage change in velocity per day for the total sample and each Group is presented in Figure 1. A one way factorial analysis of variance showed significant differences between the Groups. ($F = 4.55$, $p = 0.02$). At $p<0.05$ there is a significant difference between Groups A and D, B and D, and C and D.

The mean percentage change in velocity between days 1–15, 15–30, 30–45, 45–60 and 60–75 for the total sample and the Groups is

Table 1. Percentage Gain in Velocity per Fifteen Day Cycle during Gait Retraining

| Patients | | Duration of Gait Retraining (Days) | | | | |
|---|---|---|---|---|---|---|
| Group | Number | 1–15 | 15–30 | 30–45 | 45–60 | 60–75 |
| A | 3 | 75.30 | 10.50 | * | * | * |
| B | 5 | 43.00 | 37.30 | −2.70 | 19.1 | * |
| C | 6 | 26.40 | 39.30 | 30.00 | 6.60 | * |
| D | 5 | −7.20 | 2.20 | * | * | * |
| A–C | 14 | 55.70 | 31.20 | 20.30 | 10.30 | −0.50 |
| A–D | 19 | 29.70 | 25.80 | 23.70 | 8.83 | −6.00 |

*As the number of patients decreased with length of the gait retraining programme, cells of $n < 3$ were deleted.

illustrated in Table 1. Initial and discharge velocity and symmetry (difference between the duration of single limb stance on prosthetic and non-prosthetic limb), ambulatory aid, age and length of rehabilitation stay is presented in Table 2. The same characteristics are displayed in Table 3 for vascular (n = 16) and nonvascular (n = 4) Groups. Figure 2 represents a correlation between initial velocity and final velocity (r = 0.78) and Figure 3 shows the correlation between initial and final symmetry measures (r = 0.50).

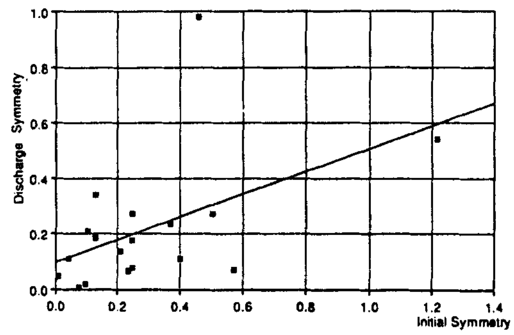


Fig. 3. Change in Symmetry in all Subjects Over the Period of Gait Training

(Pearson Correlation r = 0.50)

## Discussion

Velocity is the rate of forward progression and is the best single index of walking ability (Skinner and Effeney, 1985). Symmetry as measured by a

Table 2. Characteristics of Groups

| | Group A | Group B | Group C | Group D |
|---|---|---|---|---|
| Number | 3 | 5 | 6 | 5 |
| Age | 53.3 | 51.8 | 68.3 | 78.2 |
| Length of Stay (Days) | 90.3 | 62.2 | 70.6 | 53.0 |
| Walking Aid | Nil | 1 Stick | 2 Sticks | Frame |
| | | | | |
| Initial Velocity | 32.6 | 26.7 | 17.9 | 11.3 |
| Discharge Velocity | 70.3 | 53.3 | 35.6 | 9.7 |
| Change in Velocity (%) | 115.6 | 99.6 | 98.8 | −14.2 |
| | | | | |
| Initial Symmetry | 0.14 | 0.33 | 0.32 | 0.33 |
| Discharge Symmetry | 0.06 | 0.03 | 0.14 | 0.46 |
| Change in Symmetry (%) | 57.1 | 90.9 | 56.2 | −39.3 |

Table 3. Characteristics of Vascular/Nonvascular Groups

| | Vascular | Nonvascular |
|---|---|---|
| Number | 16 | 4 |
| Age | 73.1 | 33.0 |
| Length of Stay (Days) | 64.0 | 79.0 |
| | | |
| Initial Velocity | 17.8 | 30.1 |
| Discharge Velocity | 37.4 | 62.0 |
| Change in Velocity (%) | 110.1 | 106.0 |
| | | |
| Initial Symmetry | 0.21 | 0.56 |
| Discharge Symmetry | 0.02 | 0.02 |
| Change in Symmetry (%) | 90.5 | 96.4 |

comparison of the duration of single limb stance on either leg indicates that limb's willingness to accept the body weight. Even weight-bearing on the prosthetic and non-prosthetic side is encouraged during gait training sessions. Velocity and symmetry therefore were selected as indicators of gait training progression.

The major velocity increases in amputee gait retraining programmes occurs within the first thirty days. Table 1 displays the percentage gain in velocity per fifteen day cycle during gait retraining. The total subject result is displayed, then the sub-groups as determined by ambulatory aid at discharge and finally the Group score minus Group D (frame walkers) as Group D was found to respond to the gait training programme in a significantly different ($p<0.02$) manner (Fig. 1). Overall, patients (excluding group D), can expect around 55% increase in velocity between day one and day fifteen followed by a 30% increase between days fifteen to thirty of the gait retraining programme. As the programme lengthens the percentage gain in velocity decreases until such a time as negative gains are recorded. The better the walking outcome of the Group the greater the velocity gain within the first 15 day cycle, with Group A recording a 75% gain in velocity during this period. Overall, subjects (excluding group D) experienced approximately 100% increase in velocity from initial velocity to discharge velocity during the gait training period.

Group D patients were the oldest, required a walking frame at discharge and had the slowest initial velocity. Their initial symmetry was comparable to Groups C and B but it must be remembered that the initial testing was done within the parallel bars, a very stable support. The discharge velocity and symmetry measures for Group D patients were lower than their initial measurements. Group D patients averaged 15 days gait retraining within the parallel bars approximately twice that of the other Groups (A = 8.6, B = 7.5, C = 7.0). Three patients within Group D returned home, one went to a special accommodation house and the other to a hostel. In terms of accommodation outcome Group D patients were successful.

The aim of this pilot study was not to identify criteria necessary for selection into a gait training programme but simply rather to look at the pattern of gait recovery during the training period. Gaining information on how patient groups respond to gait training should enable therapists to intervene at the most appropriate time and ensure each patient spends no longer than absolutely necessary within such a programme. Older patients with low initial velocity should be carefully monitored. It is not necessary to have expensive gait analysis equipment as velocity can be easily measured with a stop watch within the parallel bars. Once the group average of 7.5 days within the parallel bars is reached all patients' progress should be carefully reviewed. Only those patients with particular difficulties which threaten their safety (eg. unreliable knee control in the above-knee patients, poor self-monitoring) could need their time spent in the parallel bars extended.

No relationships could be found between velocity or symmetry and progression of ambulatory aid. Therapists stated the progression of an ambulatory aid, (bars → single sticks), was largely based on the patient's confidence level.

Six patients experienced skin breakdown during the gait training programme (A = 1, B = 1, C = 3, D = 1) which resulted in a mean loss of 13 days gait training. The total stay for the patients (n = 6) with skin breakdown was 91.5 days compared to the group average of 66.9 days. These patients all had discharge velocity scores in excess of the average discharge velocity scores for their respective groups. One subject missed 25 days as a result of problems with the remaining foot but he also was discharged with a velocity higher than his group's average.

There was an average of 22.4 days (range 10–59) between amputation and admission to Caulfield Hospital. The total stay at Caulfield Hospital was 66.9 days. 55% of the subjects had both in-patient and out-patient programmes. The average in-patient stay being 36.4 days and the average out-patient stay 55.4 days. The total time from amputation till discharge from rehabilitation was 89 days. This figure compares closely with previous Australian studies (Hubbard and Hurley, 1988; Katrak and Baggot, 1980).

Like previous studies, Table 3 indicates that patients who require amputation for reasons other than vascular problems do well with regards to walking speeds. It is interesting to note that as a rule of thumb an 100% increase in velocity from initial to discharge measurement over a gait retraining period appears to be the norm.

**Conclusion**

This is a pilot study with a small group of patients. Firm conclusions cannot be reached. Several trends however are interesting.

The following may be suggested: Major velocity gains are made within the first 30 days of a gait retraining programme. Initial velocity scores recorded within the parallel bars can be used to predict discharge velocity. Skin breakdown although elongating the rehabilitation phase does not detract from final velocity outcome. Subjects who do not show velocity gains within the parallel bars after the average stay of seven days should be encouraged to try a frame unless unsafe as prolonged stay within the bars has not been shown to enhance final velocity.

Further studies should be carried out to learn more about gait training programmes. Therapists must have sufficient objective data to determine patients' progress and the plateaux in performance, in order that this group of patients with a poor health pattern and high mortality rate post-amputation should spend the least amount of time required within gait training programmes.

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