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IMPROVED GAIT FACILITATION BY OPTIMIZED PERONEAL STIMULATION

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Abstract

Peroneal stimulators (Philips) were modified to allow various settings of the stimulus train duration and stimulus delay from the triggering at foot-sole-to-floor contact of the contralateral foot. The effects on gait pattern at different settings of the stimulation parameters were assessed in patients with spastic pareses from gait recordings by means of intermittent light photography. After individual adjustment of the stimulus delay and duration, the stimulators were used in long-term trials including comparison of the delayed stimulation with that of undelayed stimulation. The results show that individual adjustments of stimulus delay and duration may improve the gait facilitation of peroneal stimulation.

Introduction

Peroneal stimulation with a stimulator carried by the patient has been found to be a useful aid for some patients with toe-dragging due to central paresis. A few types of stimulators with some differences in the detailed design are commercially available. Two principles of starting the stimulation are used. Both work with switches or equaivalent arrangements on one of the feet. The stimulation starts either at the heel-off of the paralysed side or at foot-sole-to-floor contact of the contralateral foot. Since the timing of the different phases of gait is highly various in different patients it may be assumed that an individual adjustment of the delay besides the adjustments of duration possible in some commercial stimulators, might further improve the gait facilitation obtained by peroneal stimulation. To test this, a Philips stimulator was modified to allow a free choice of delay and duration of the stimulus train. Various stimulation parameters were then tested and compared to heel lift triggering. After adjustment of the stimulation to obtain optimal gait facilitation, the stimulators were tested during long-term trials. The findings support the view that including a variable delay in peroneal stimulators has several advantages.

Material and methods

Three patients with abnormal gait due to central pareses of long standing were admitted to the study. They all had unilateral toe-dragging during walking. Two of them could walk without aid but preferred using a walkingcane. One walked with crutches.

Philips peroneal stimulators were modified with an additional electronic unit described below, permitting a stimulus delay variable between 0 and 1 s. The unit also gives variable stimulus duration between 0.3 and 2 s.

The gait was analyzed with a photographic method. Reflective targets were attached to the lateral aspect of foot, lower leg and thigh. The patient was then photographed with the shutter open during walking in intermittent light from a stroboscope. The gait pattern can thus be visualized and the effects of different adjustments of stimulation parameters assessed. The long-term effects were evaluated from similar records and from interviews with patients. Also a step counting circuit was applied on the stimulator for long-term counting.

The foot-to-floor contacts were recorded by the use of 3 switches fastened to each foot indicating the floor contacts of the heels, soles and toes.

Technical description of the stimulator

The additional circuitry needed to obtain a variable delay and duration consists of two monostable flip-flops with variable time-constants, connected in series. The first one is triggered by the ordinary insole and circuitry of the Philips stimulator. Thus the first flip-flop gives the delay. The second flip-flop controls the stimulation activity via a transistor switch and gives the stimulation duration. The flip-flops are built with CMOS IC:s to get a low quiescent current drain.

The circuitry is completed with a step counting circuit according to the event counter system presented in another paper at this Dubrovnik meeting.

The circuit board is placed in the compartment of the stimulator box designed for the battery. See Fig. 1. The battery is instead put into a separate battery carrier attached to the side of the stimulator. The battery is fixed by a Velcro-band (Fig. 2). The delay and duration are adjusted with trimpotentiometers.

Of course this practical solution should not be seen as a definite way to build this more flexible type of stimulator. At a series production these circuits should be integrated with the rest of the stimulator on one PC-board.

Results

Patient A had a spastic hemiplegia on the left side with a motor dysfunction characterized by servere paresis and a slight degree of spasticity. Fig. 3 shows the timing of the foot-to-floor contacts during walking. The most prominent deviation from normal pattern was a short interval between heel and sole contacts due to insufficient toe elevation at weight acceptance of the paralyzed left leg.

Fig. 4 A shows a record of the walking without stimulation. In spite of a passive, almost straigt leg and lack of normal toe elevation, the swing-through was accomplished by circumduction and hip elevation. During the stance phase knee hyperextension was quite prominent.

Gait pattern during peroneal stimulation is seen in Fig. 4 B and C. In B the Philips stimulator without modification was used and in C a stimulus delay of 0.2 s was introduced. The puls train duration was 0.8 s in both records and sti-

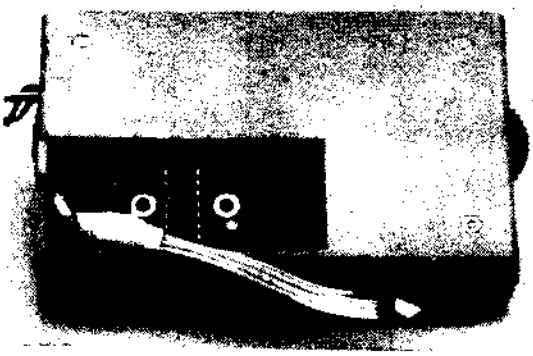

Fig. 1. View of the stimulator with the additional circuitry and connector for step counter.

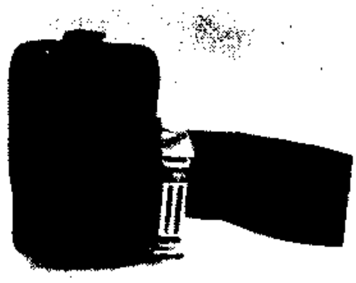

Fig. 2. Stimulator with external battery carrier.

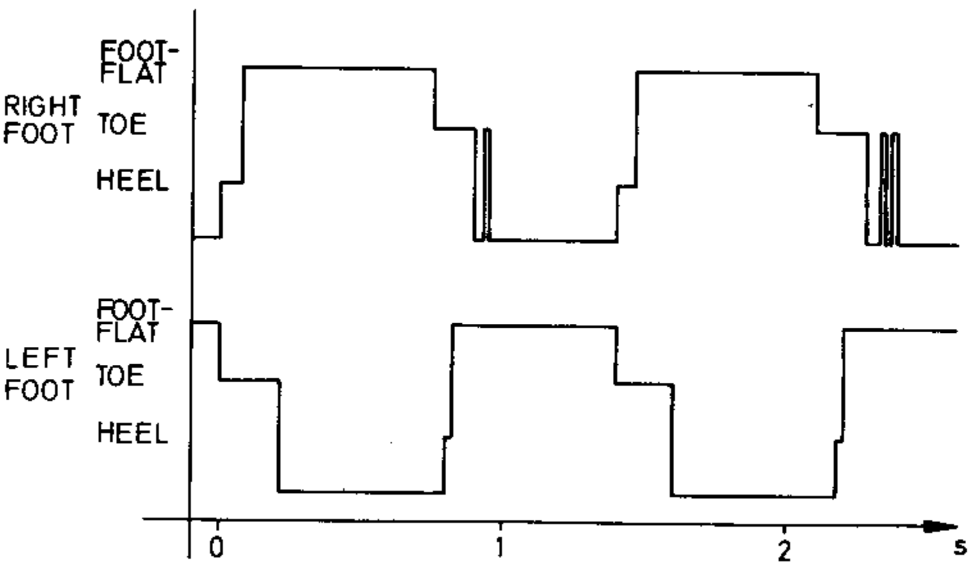

Fig. 3. Diagram of foot-to-floor contact during walking, patient A, without stimulator.

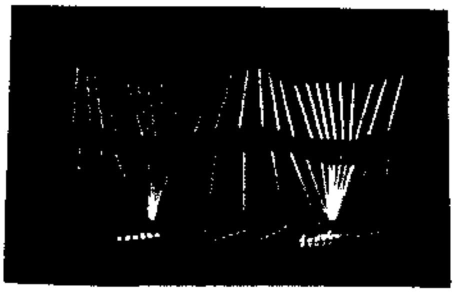

Fig. 4 A.

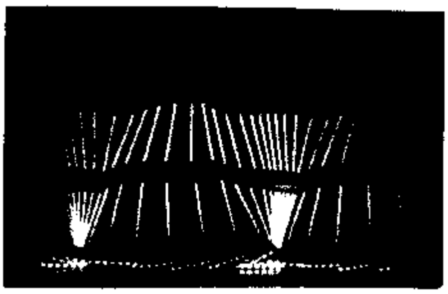

Fig. 4 B.

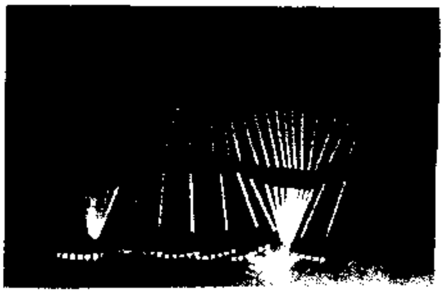

Fig. 4 C.

Fig. 4. Gait records of patient A without stimulator (4A), with unmodified stimulator (4B) and with modified stimulator (4C). Stimulus train duration 0.8 s in 4B and 4C. In 4C, stimulus delayed 0.2 s. Strob light frequency 10 Hz.

mulation amplitude was identical. In both records there is a prominent toe elevation during the swing phase and the step length is increased. A slight decrease of the knee hyperextension may also be discerned. This effect may be due to the fact that stimulation continued into the stance phase. As seen in the records the elevation of the leg during swing is more pronounced with the delayed stimulation. The optimal setting of delay and stimulus duration was found to be 0.2 and 0.8 s, respectively. The setting derived by the objective analyzis agreed well with the opinion of the patient.

As can be seen in Fig. 3, the optimal delay, 0.2 s, will result in a stimulation that start after push off early in the swing phase. The optimal duration, 0.8 s, implies that stimulation continues into the following stance phase.

Over a period of 5 month, patient A walked 3 000 steps per day in average and reported sustained benefit.

Patient B was paraparetic due to multiple sclerosis. The paresis was moderate and the degree of spasticity was slight. The weight acceptance of the left side was made with foot-flat and toe dragging was frequent on this side. The optimal setting of delay and duration of the stimulation was 0.2 s and 0.8 s, respectively, as in patient A. Comparison of a conventional heel lift triggered stimulator and the optimised, modified stimulator during longer periods, revealed a better acceptance of the modified stimulator. No significant differences were, however, observed in the gait records. The patient reported a more rhythmic gait with less effort during walking. In average, 5 000 steps per day with the peroneal stimulator were recorded during a one month period with a good acceptance throughout this time.

Patient C, with tetraparesis due to multiple sclerosis had relatively good isometric muscle strength and servere spasticity. Walking was possible with crutches, the step length beeing very short and movements slow. Feet contacts with the floor is seen in Fig. 5 that shows a prominent toe-dragging of the right foot and lack push-off.

Optimal setting of the stimulation parameters were 0.5 s for both delay and duration. As can be seen in Fig. 5 the optimal delay will result in a stimulation starting at the toe-dragging period. A heel lift triggered stimulation results in an approx. 0.3 s earlier start of the stimulation. The patient preferred the delayed stimulation as compared to the heel-lift triggered one when tried over one week periods. The preference of the contralateral triggering was due to easier initiation of walking, while the delay was preferred due to the fact that the stimulation period could be kept shorter with equal effect on the toe-dragging. The step meter device counted 1 750 steps/day in average over a fortnight.

Discussion

The result of the present study shows that the possibility to individually adjust the peroneal stimulation is of great value. Due to the great variability in the gait disturbances with toe-dragging there is no regular relation between a certain trigger point in the gait cycle and the swing phase. One advantage with an adjustble delay seems to be that stimulation during push-off can be avoided as in case A and as probably also in case B. Another advantage observed in case C is that the stimulation span can be restricted to the very period of toe-dragging. This implies a reduced battery energy demand and diminish the strain on the skin at the points of stimulation. In patients without difficulties in gait initiation, the choice of triggering foot is of no great importance provided a variable delay of the stimulus is possible. However, when gait initiation is difficult the choice of triggering point may be crucial.

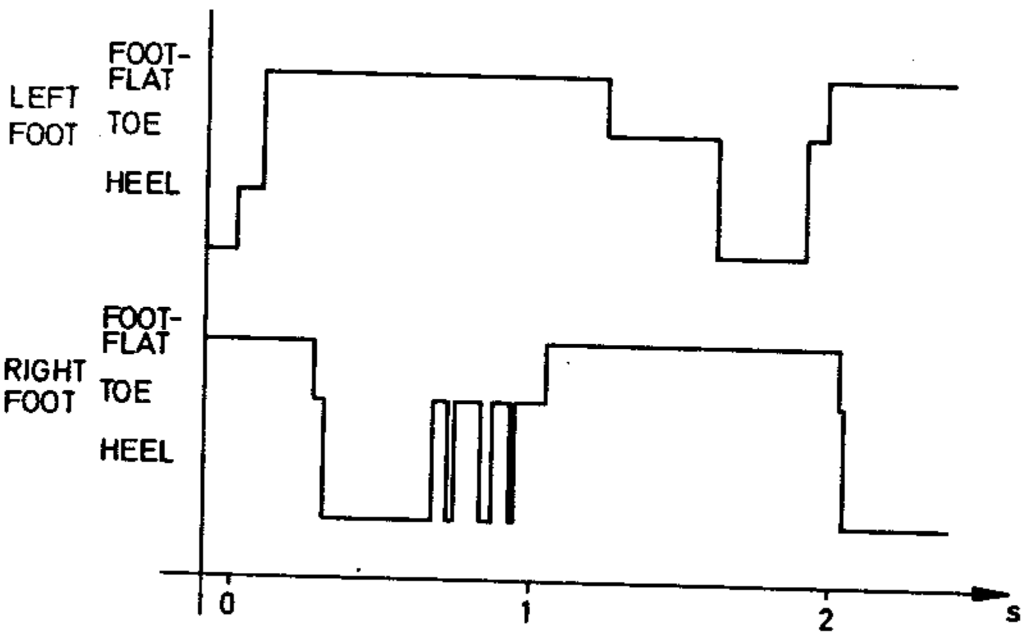

Fig. 5. Diagram of foot-to-floor contact during walking, patient C, without stimulator.

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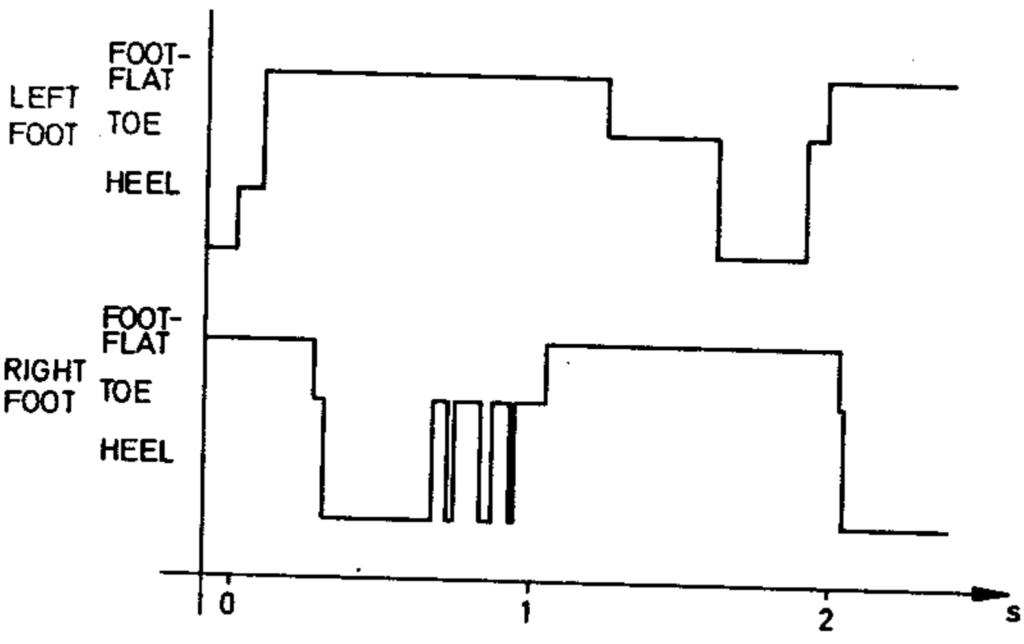

Fig. 5. Diagram of foot-to-floor contact during walking, patient C, without stimulator.