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BIOFEEDBACK TREATMENT OF GENU-RECURVATUM USING AN ELECTRO GONIOMETRIC DEVICE WITH AN ACOUSTIC SIGNAL

One-year Follow-up

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ABSTRACT. **The aim was to evaluate the effect of a biofeedback electrogoniometer in the control of recurvation of the knee while walking in patients with neurological diseases. Eighteen patients were trained daily for 12.8 sessions on average with an electrogoniometer attached to the knee, which gave a signal at a threshold value of 180° in order to avoid hypertension of the knee. The improvement was statistically significant even after one year.**

Key words: hemiplegia, biofeedback, genu-recurvatum.

Genu-recurvatum is frequently observed during stance resulting from lesions to the central nervous system. The recurvatum gives a "passive" stability to the affected limb during stance but this condition, in hemiplegic patients, is mostly an excessive compensation which tends to establish itself permanently and to interfere negatively in the recovery process.

In fact, this compensation, besides altering the quality and aesthetics of gait, distorts the afferent information by favouring the acquisition of poorly functional walking patterns and an awareness of abnormal body movements in relation to space. Furthermore, the persistence of a recurvatum favours shortening of the calf muscles and thus tends to maintain such a position.

Many authors have drawn attention to the risk of anatomical damage involved, with a persisting recurvation. Such impairment is due to changes in load distribution on the articular surfaces and to straining of the posterior part of the capsule and cruciate ligaments.

Anatomical damage may be negligible in patients with a serious neurological outcome, poor walking autonomy, and a reduced stance phase, whereas it becomes a great problem in younger, or less seriously damaged patients whose walking ability is more favourable, in overweight patients, and in those who must maintain a standing position for long periods.

In 1978 Simon et al. (9), by studying the gait of spastic children with cerebral lesions, were able to distinguish at least two types of genu-recurvatum. They described one group in which the recurvation appears early in the stance at about 20% of the gait cycle and another group with a later appearance of the hyperextension of the knee in the mid stance, at about 40% of the gait cycle.

The abnormal response to the stretching of the calf muscles which occurs during tibial advancement after the sole of the foot has been firmly placed on the ground, could be responsible for the recurvation only in the first group; in fact, the authors did not detect any increase in electromyographic activity of the calf muscles and hamstrings in the second group.

Knutson & Richards (6) noticed that recurvatum in hemiplegic adults was mostly observed in association with premature activation due to hyperactivity of the stretch reflex of the calf muscles, but it also occurred in patients with abolition or marked lowering of the EMG activity of the paretic limb, and at times in those who presented abnormal coactivation of several of the limb muscles.

Since 1984 (1), our group has been investigating treatment of hyperextension of the knee in adults with cerebral lesions, using an electrogoniometric device with auditory feedback (BFB-EGM), which can provide reliable detection and reveal the degree of articular extension after a pre-established threshold has been overcome.

Few studies have been found in literature, on the treatment of hyperextension of the knee during the stance phase of gait, with biofeedback.

Hogue & McCandless (5) using an electrogoniometric feedback in 13 hemiplegic patients obtained

Table I. *General information concerning the patients*

No.	Age	Sex	Sensitivity tact.-kinest.	Aphasia	Walking aids	Treat. days
Stroke with right hemiparesis						
1	67	F	Unaffected	–	–	11
2	51	F	Unaffected	–	–	15
3	56	M	Unaffected	–	–	14
4	51	F	Unaffected	–	Stick	14
I.C.P.						
5	19	F	Unaffected	–	–	5
Stroke with left hemiparesis						
6	67	F	Unaffected	–	–	21
7	71	M	Unaffected	–	–	13
8	24	F	Unaffected	–	–	30
9	65	M	Unaffected	–	Stick-AFO	11
10	60	M	Unaffected	–	–	14
11	61	F	Anesthesia	–	–	10
Head injury with left hemiparesis						
12	9	F	Unaffected	–	–	14
13	17	M	Anesthesia	–	–	6
I.C.P.						
14	19	F	Unaffected	–	–	5
Stroke with left hemiparesis						
15	43	F	Unaffected	–	–	8
16	25	F	Unaffected	–	–	5
Stroke with right hemiparesis						
17	63	M	Unaffected	–	–	11
18	65	F	Unaffected	Aphasia	Stick	24

good results in the control of hyperextension. Koheil & Mandel (7), using an electrogoniometric feedback to obtain control of the knee during the stance phase in a well conducted single case study, noted dramatic improvement of the recurvatum. Fernie et al. (4) utilized a similar device to train 19 above-knee amputees in the safe operation of their prosthesis by maintaining the knee joint in extension throughout the stance phase. The authors observed that 15 patients benefited to some degree from the treatment.

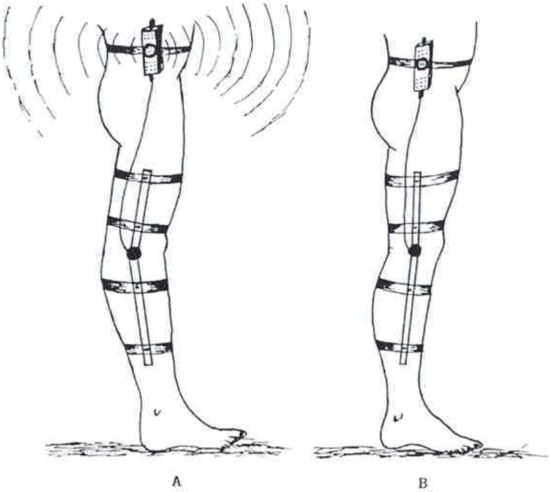

Fig. 1. Electrogoniometer in recurvatum (A) and in correct position in extension (B).

In a previous report (2) we presented the markedly positive results we had obtained in 14 patients using the BFB-EGM technique. In the present investigation we aimed at verifying the degree of stability obtained in the control acquired by the patients treated with BFB of genu-recurvatum.

MATERIAL AND METHODS

Eighteen patients with CNS lesions underwent the treatment. Patient selection was based on the following criteria:

- presence of recurvation of the knee in at least one-third of the steps
- walking unassisted
- no articular limitations

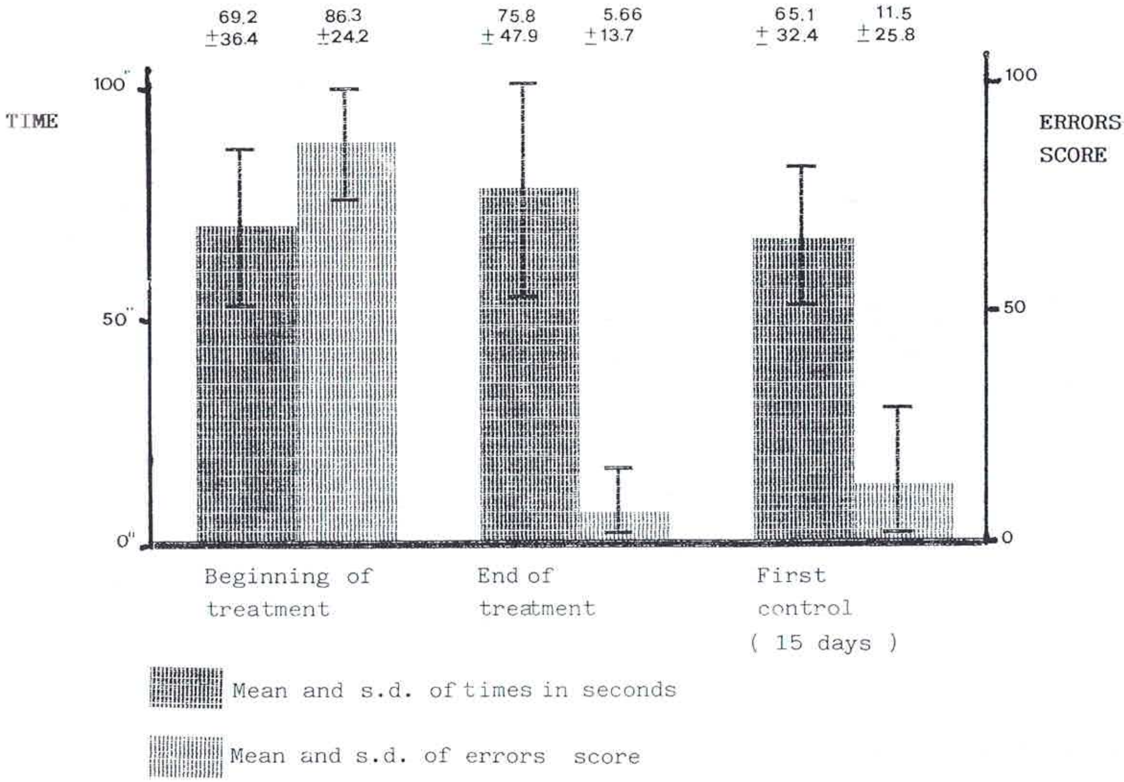

Fig. 2. Histogram relative to 18 patients showing the time taken to walk at free speed and the errors score (beep).

- ability to perceive the acoustic signal without presenting serious difficulties in decodification.

Besides the patient's personal data, the degree of tactile and kinesthetic sensitivity, presence of disturbed cortical functions, use of walking aids and length of treatment were recorded. Differences in degrees in recurvation were not taken into consideration. General information concerning the patients is reported in Table I.

Treatment

The patients were required to put on the electrogoniometer and follow a pre-established walk under the guidance of a physiotherapist. The electrogoniometer used in our department (3) is a simple device which can be regulated to a "threshold" value equal to the desired joint angle so that the device beeps when the patient exceeds this angle.

It is composed of angular movement compasses whose metallic poles, fixed along the axes of the leg and thigh by means of a velcro strap, articulate on a potentiometer balanced at the level of the fulcrum of the joint (Fig. 1). The potentiometer is connected to an electronic signal processor, whose size and weight are not more than those of a pack of cigarettes, attached to the patient's belt. In this device there is an auditory signal of varying intensity which emits a continuous, proportional sound every time the patient exceeds a certain degree of extension, and terminates when the knee changes this position.

Initially, the auditive signal was used as a cognitive input capable of activating in the subject those cognitive processes suitable for the acquisition of a specific control of the joint. The patient was therefore asked to concentrate particularly on the behaviour of the affected knee by correcting any mistakes indicated by the signal at the moment of activation. Then, once voluntary control of the knee had been acquired, the patient's attention was distracted from knee control and the auditive signal was used as a signal for error in a motor sequence which was to become automatic.

The aim was to go from one cognitive activity with careful continuous control of the monitored segment to a rapid, automatic motor activity, less carefully controlled. The tests were carried out for 40 min every day, five days a week. The training was interrupted when the patient achieved a stable reduction in, or elimination of, mistakes for at least 5 consecutive days.

Evaluation

The patients were evaluated at the beginning of treatment, at the end, and 15 days after the end of treatment; 13 patients were also evaluated 30 days, 3 months and 12 months after treatment. The parameters calculated for each patient were:

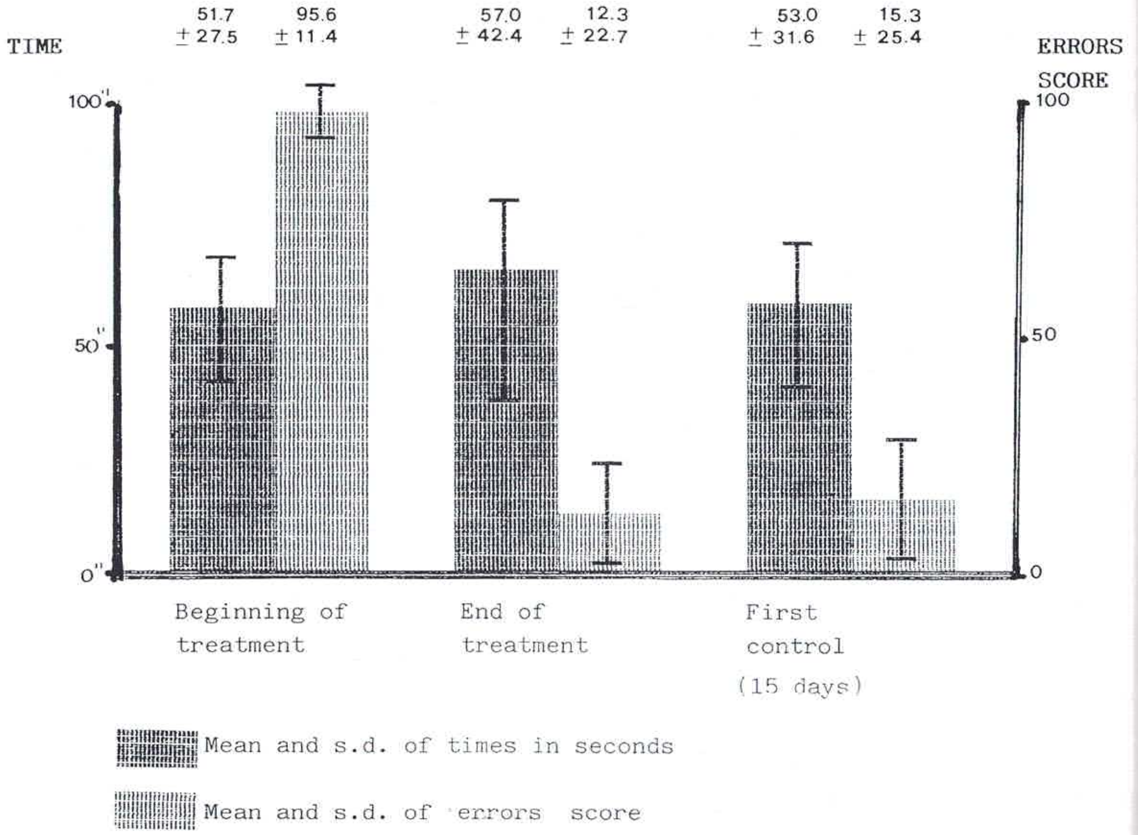

Fig. 3. Histogram relative to 18 patients showing the time necessary to walk the distance at maximum speed allowed by lesion and number of errors (beep) on total number of steps taken.

- the time taken to walk 30 m on flat ground at free speed;
- the time taken to walk 30 m on flat ground at best possible speed;
- the error score: calculated as the percentage of mistakes (recurvatum during stance) made by each subject during the trials.

The statistical analysis was carried out using the Wilcoxon test for paired data with a level of significance of $p<0.01$.

RESULTS

Free speed walking showed significant improvement in error score at the end of treatment and at the control compared with the beginning of treatment ($p<0.01$, $n=18$), whereas the time taken to walk 30 m did not show any statistically significant variations (Fig. 2).

Even at maximum speed the decrease in beeps was statistically significant at the end of training as well as at the first control ($p<0.01$). Similarly, no changes were observed in the time values (Fig. 3).

Fig. 4 shows the values recorded at free speed for 13 patients at the beginning of treatment, at the end of treatment, after 15 days, and after one month, three months, and one year following treatment.

The reduction in the number of errors continued to be statistically significant at the one year follow-up ($p<0.01$) compared with the beginning of treatment, and the values for speed did not show any significant difference.

Fig. 5 refers to the values recorded during the maximum possible speed for the same group of 13 patients. It may be seen that the results did not differ from those obtained at free speed: the time taken did not change significantly in the various tests; moreover, the error score showed a significant improvement at the end of treatment and at the follow-up as compared with the beginning of treatment ($p<0.01$).

There are few reports in the literature on a follow-up of over one year in patients given BFB

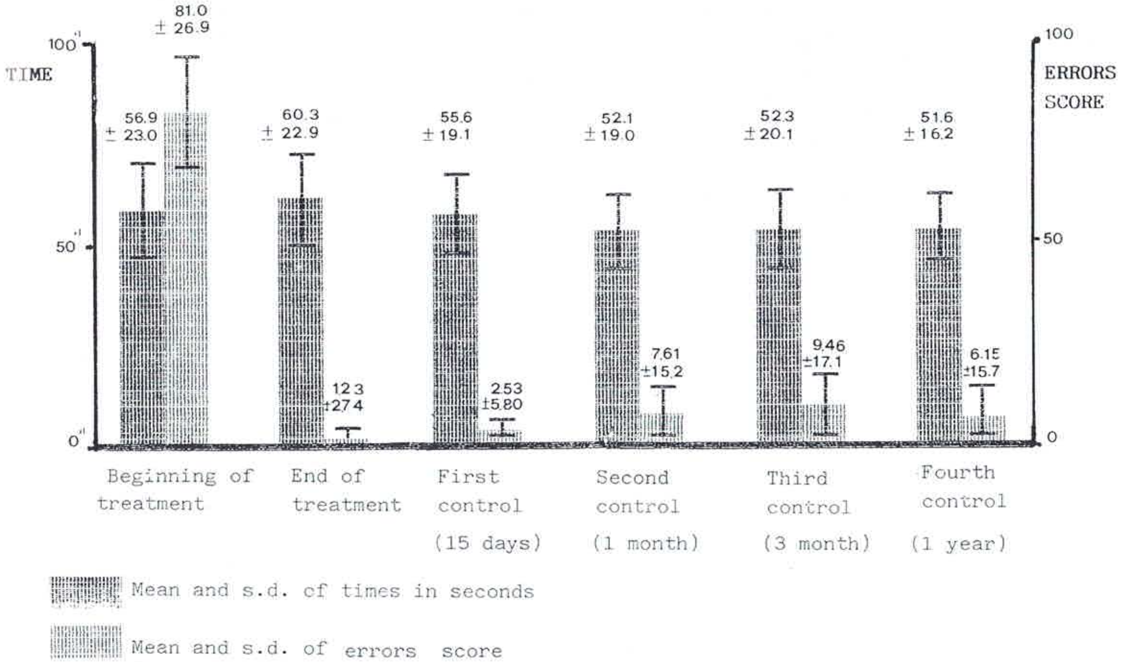

Fig. 4. Histogram relative to 13 patients showing the time taken to walk at free speed from beginning of treatment up to follow-up 1 year later and number of errors (beep) on total number of steps.

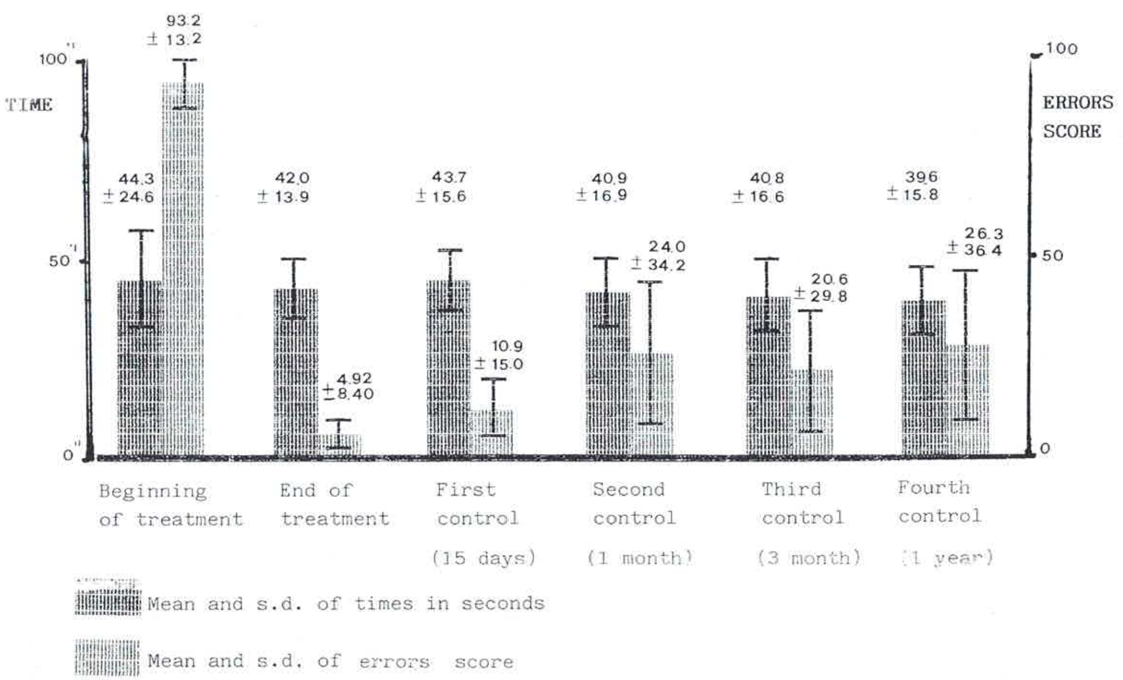

Fig. 5. Histogram relative to 13 patients who walked 30 metres at maximum speed, showing the time of segment and number of errors recorded.

goniometric treatment. In a one-year follow-up study, Wolf et al. (10) reported no deterioration in performance in 34 subjects who were treated using EMG-BFB. Seeger & Caudrey (8), evaluating the long-term efficacy of the treatment of three children, found that most of the therapy gains had been lost after treatment had ended. Our patients, on the other hand, still maintained the therapy gains one year after the end of treatment, perhaps because, unlike Seeger's patients, they were adults and thus more motivated. However it must be remembered that patients with motor impairment often perform better during medical evaluation than they would do normally.

CONCLUSION

The results of this study show that the patients have achieved a significant reduction in recurvation of the knee with the BFB-EGM technique and that such control is maintained one year following treatment. An important advantage of this technique is the rapidity with which the desired results are obtained; on average 12.8 sessions were necessary even for patients who had not achieved any results with other types of treatment.

Of particular interest are the uses of the feedback signal according to a scheme which is very similar to what happens in the normal individual's control of movement.

In fact, the patients initially use the feed-back in order to get to know the exact moment of the decrease in hyperextension, its entity and duration in the walking cycle.

Once they are able to control such an alteration, the feedback will serve exclusively as a sign of error.

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