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FES IN THE EXTERNAL CONTROL OF SOME MECHANISMS IN IDIOPATHIC SCOLIOSIS

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SUMMARY

With respect to the hypothesis that idiopathic scoliosis is produced by the changes in sensorimotor mechanisms in 19 children with idiopathic scoliosis (IS) has been analyzed:

1. findings of clinical results
2. patterns of EMG activities of the paravertebral muscles during functional movements of the trunk and loading of the spine
3. results of the frequency analysis of EMG potentials of the paravertebral muscles
4. behavior of sensorimotor bio-feedback mechanisms organized on the level of the spinal cord and cortical level
5. effect of programmed electrical stimulation as a kind of external control on the activity of the paravertebral muscles and change of scoliotic deformity
6. possible solutions of biological-hardware interface of the FES systems.

Both positive and negative effects of the FES have been illustrated, and a correlation between clinical and electrophysiological findings determined. Possible mechanisms responsible for the onset and development of IS as well as therapy procedures applied for the external control of organization of motor activity and posture have been discussed.

INTRODUCTION

Investigations carried out thus far have shown that changes in idiopathic scoliosis are not primarily caused by any derangement of the mechanical proterties of ligaments and tendons or by laxity of the joints and that deformity is produced by an extraosseus cause (1, 2). More than that the reasosn may also be in the primary affection of the brainstem during the period of rapid growth (3) or in various samples of the activation of the paravertebral muscles (4). Furthermore, they have indicated that in animal experiments permanent stimulation my cause scoliosis as well (5). All these investigations allowe new approach in the treatment of idiopathic scoliosis. With this respect we tried to exert an active influence upon muscle contraction and to activate proprioceptive reflex mechanisms using functinal electrical stimulation (FES) (6).

At the same time we also applied the analysis of EMG activity of the paravertebral muscles, mono-, and polysynaptic reflex activity and voluntarily controlled responses to both visual and acoustic stimuli with a view to explaining various changes in the organization of motor activity.

PATIENTS AND METHODOLOGY

Patients

For the study 19 children were selected. These were subject ranging in age from 4 to 18 years with a diagnosis of idiopathic scoliosis (IS). They were all hospitalized with a view to receiving programmed therapy. 6 children had double, 7 thoracic, 3 thoracolumbar and 1 lumbar curve scoliosis.

Electrophysiological analysis

a) Patterns of EMG activities of the paravertebral muscles during functional movements of the trunk and loading of the spine, particularly the m.longissimus dorsi by Morris, J.M. at all (7). Detection was performed using disc electrodes, and registration with the Van Gogh polygraph. Pairs of electrodes were placed on both sides of the spine above and in tle level of the curve and under it whenever possible.

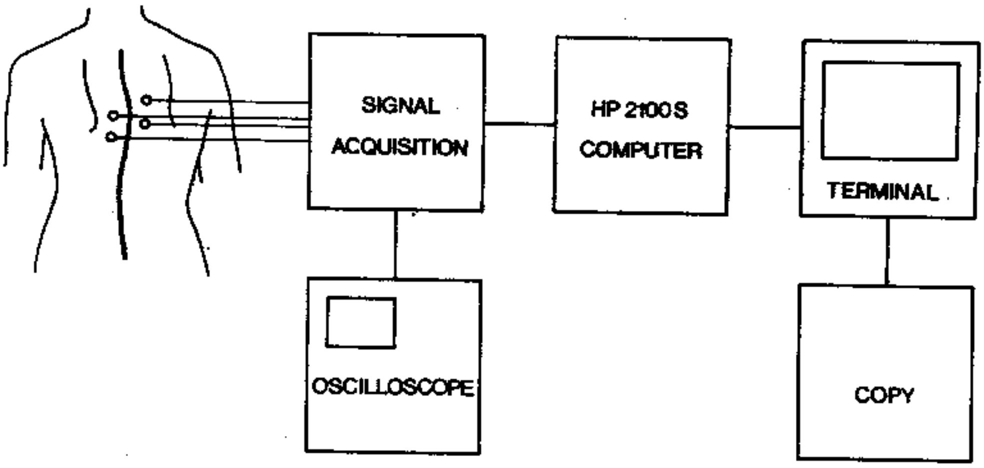


Fig. 1 Blok Diagram of the Frequency Analysis of EMG Potentials

b) The frequency analysis of EMG potentials of the paravertebral muscles with detection in the area of the concavity and convexity of the curve. The EMG signal was amplified with an differential amplifier with a bandwidth of 1KZz. It was sampled with a frequency of 3KHz and analysed by means of the fast Fournier method on the digital computer HP 2100S. The duration of single segment was 0,3 sec. The autocorrelation of the EMG signal was performed at the same time as the above analysis. The EMG activity was sampled successfully some times.

c) Motor reflexes of the biceps, triceps, patelar and Achilles reflex as well as the flexion response to nociceptive stimulation of the plantar surface and detection out of the anterior tibialis muscle were analyzed electrophysiologically.

d) Detection of the voluntarily controlled muscle contraction in the flexors and extensors of the fingers and wrist, measurements of the size of the responses and the involved latency that follows a visual or acoustic stimulus.

All these children were tested with FES, i.e. a bipolar technique of stimulation (8) with the following parameters of stimuli: t = 0,5 ms, f = 40 Hz, duration of train = 1,4 s, pause between trains = 2 to 4 sec, voltage more than 30 V. The AM-5 stimulator (Rehabilitation Institute, Ljubljana) was used. In the majority of the cases the electrodes were located in the area of the curve convaxity, and in a few other cases more laterally in the area of the angulus caudalis or margo lateralis scapulae. Testing was administered with the patients prone. Changes were clinically observed. In positive cases the standing X-ray of the spine was taken before and during the FES of the paravertebral muscles in the area of the curve convexity.

In 5 children with a positive effect the stimulation of the paravertebral muscles was continued for two weeks and that twice 20 minutes a day.

Fig. 2 Placement of the stimulation electrodes and correction of the spine deformity

In order to meet the needs of our experiment and therapy program with a technique of bipolar surface stimulation the electrode knob (FES systems, Rehabilitation Institute) and stimulator AM-5 were applied. The electrodes were fastened by the plastic "pelote" and elastic strap or by an adhesive micropore ribbon.

RESULTS

Table 1

No.	Case	Age	Scoliosis	Effect of FES (observation)	Degrees of curves Without FES	With FES	Comments
1.	H.B.	18	D	ø			
2.	T.D.	13	D	+	19	22	impaired
3.	B.M.	12	T	ø			
4.	V.M.	14	D	ø			
5.	P.Z.	17	D	+			
6.	T.Z.	18	D	+			
7.	H.J.	12	T	+			
8.	V.M.	16	TL	ø			
9.	K.S.	15	T	+	112		
10.	S.D.	12	L	+	45	38	
11.	G.P.	12	T	+	15	4	
12.	K.H.	4	TL	+	60	47	
13.	L.S.	7	TL	+	57	30	electrodes very laterally
14.	G.S.	10	T	+	87	76	
15.	U.D.	11	D	ø			
16.	Š.A.	16	T	+	36	26	
17.	K.P.	11	T	+	22	13	
18.	B.S.	16	D	+	19ˣ	12ˣ	
19.	P.M.	13	D	+	27ˣ	9ˣ	

x = in the prone position
D = double curve scoliosis
T = thoracic scoliosis
L = lumbar scoliosis
TL = thoracolumbal scoliosis

Clinical observation revealed that FES with the patients in the lying position achieved improvement of deformity in 14 children, and no effect at all in 5 patients.

The X-ray analysis of the spine taken in 11 children showed various degrees of correction in 10 cases and a negative effect in 1 case despite the clinical observation of improvement when the child was in the lying position. When stimulating some children with thorocic scoliosis the electrodes had to be moved more laterally because of the simultaneus contraction of paravertebral muscles in the lumbar region which caused an impairment of the lumbar lordosis.

a b c

Fig. 3 - X-ray of the spine a) before FES
b) during FES of the muscles in the area of convexity
c) after FES

The effect of the fortinight's FES in the area of the convexity of the curve in the paravertebral muscles showed that marked effects in either the positive or negative sense, i.e. improvement or impairment of the existing curve could be achieved within a relatively short period of time. Results are displayed in Table 2.

Table 2

Case	Age	Lenght of curve	No. of vertebrae involved	Degrees of curve before FES	Degrees of curve after FES	Difference
S.D.	12	$L_2 - L_5$	3	45^o	50^o	$+ 5^o$
G.P.	11	$Th_8 - Th_{12}$	5	15^o	20^o	$+ 5^o$
K.P.	21	$Th_5 - Th_9$	5	22^o	22^o	0^o
Š.A.	15	$Th_8 - L_1$	6	36^o	31^o	$- 5^o$
L.S.	7	$Th_{10}-L_3$	6	57^o	48^o	$- 9^o$

In two cases a 5^o and 9^o improvement was achieved, in other 2 cases a 5^o impairment and in 1 case no change after cessation of stimulation.

In the polyelectromyographic analysis of the patterns of the paravertebral muscles activity in the erect position, in relaxation and forward bending activity in the paravertebral muscles in the area of the curve convexity was established in 2 patients. It was present in 1 of them also during relaxation. This EMG activity prevails for its amplitude and frequency in relation to activity in other muscles. In these patients the effect of FES was negative and further impairment was observed (Fig. 4).

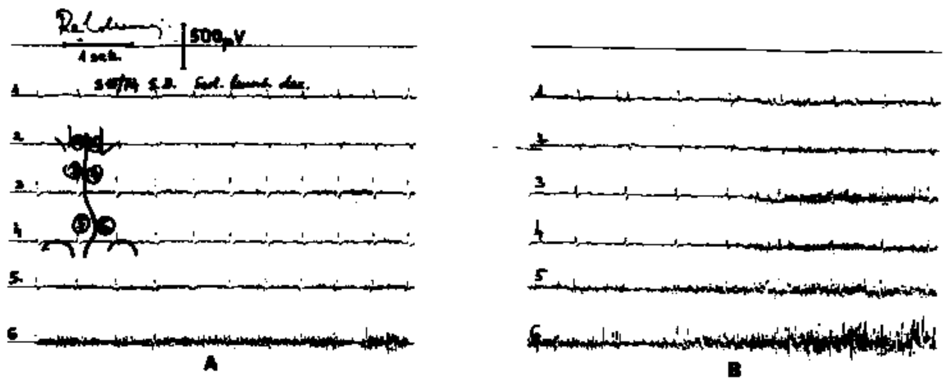


Fig. 4 Polyelectromyographic record of the EMG activity of the para-vertebral muscles in the standing position

a) in relaxation

b) in forward bending

in the paravertebral muscles in the area of the curve convexity

In 2 patients we got the pattern of motor activity with dominating EMG activity in the paravertebral muscles in the area of the concavity of scoliosis at the forward bending while electrical silence was observed during relaxation. In these patients the FES of the paravertebral muscles in the area of convexity had a positive effect on the correction of the spine and decrease of the curve (Fig. 5).

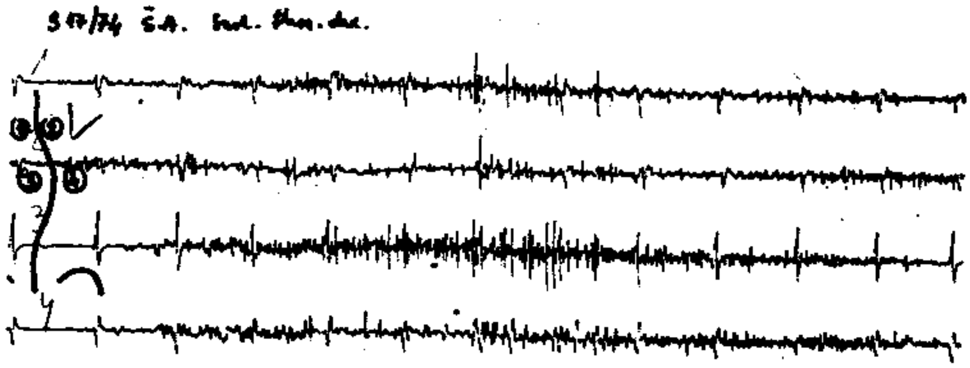


Fig. 5 Polyelectromyographic record of the EMG activity of the paravertebral muscles at the forward bending of the trunk. The EMG activity is most noticeable in the paravertebral muscles in the area of the curve concavity.

During the forward bending bilateral EMG activity on both sides of the curve (in the area of concavity and convexity) was detected in 1 child. However, it is considerably smaller than in the paravertebral muscles proximally and distally. In this child FES had no effect (Fig. 6).

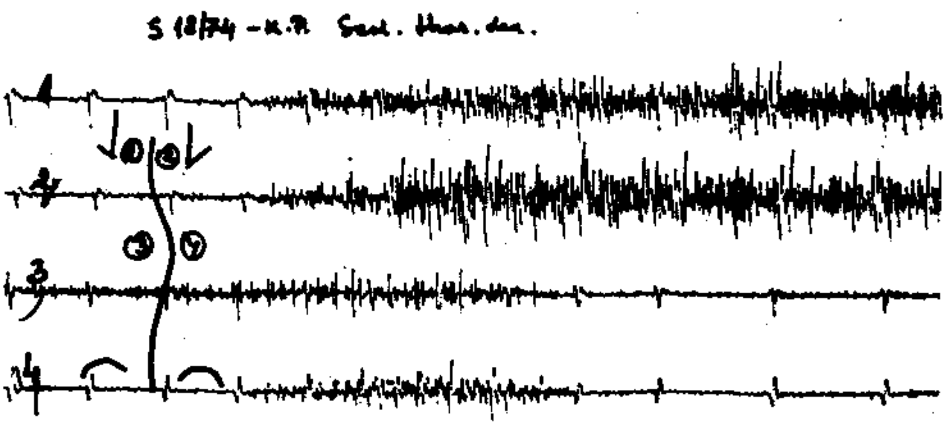
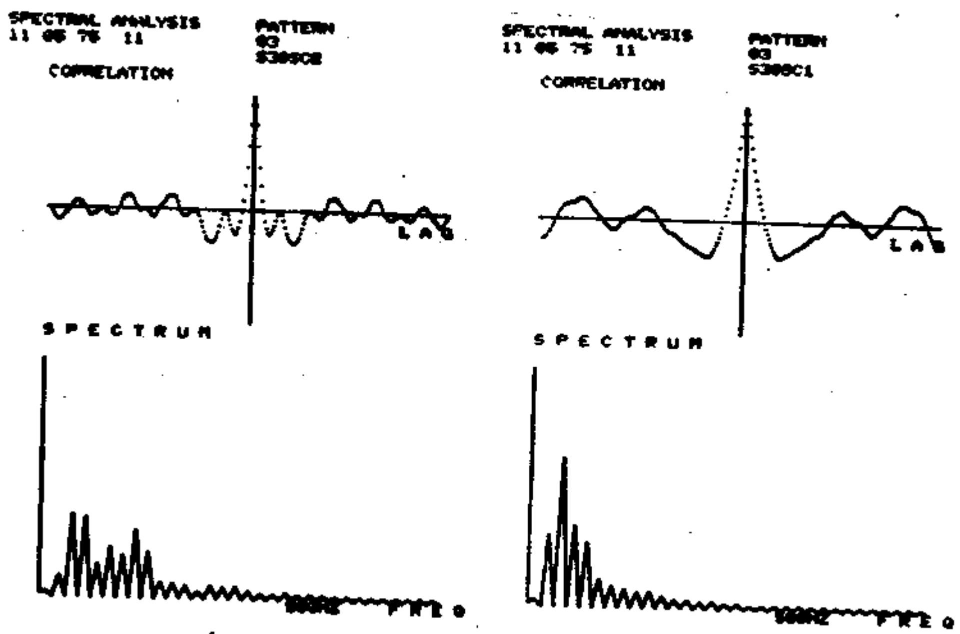


Fig. 6 Polyelectromyographic record of the EMG activity of the paravertebral muscles at the forward bending of the trunk. The EMG activity is present in the paravertebral muscles on both sides of the curve, yet somewhat less noticeable than in muscles located proximally with respect to the curve.

In the majority of the children the analysis of tendon reflexes revealed a decreased amplitude of reflex responses, particularly those of the biceps and triceps on the side of the curve convexity. On the same side flexion responses were less marked. Delays of the voluntarily controlled motor responses to both visual and acoustic stimuli were not characteristic. Those differences that were eventually present were not significant.

The frequency analysis of the EMG activity of the paravertebral muscles indicated a tendency toward a prolongation of the frequency spectrum in the muscles within the convexity area (or shifting to the right) as illustrated in Fig. 7.



A B

Fig. 7 Autocorrelation and specttral Analysis of the EMG potentials

A - on the convexity B - on the concavity

The hardware applied thus far was found to be unsuitable for independent use. It can be utilized only under laboratory conditions or in therapy purposes under the direct supervision of the physical therapist. The technique of surface stimulation does not allow a reliable fixation of the electrodes. A larger intensity of the stimulus (direct stimulation of the muscles whose threshold is higher that that of the nervous fibers) and greater sensibility of the skin (as in the case of the stimulation of the peroneal nerve) are reason for irritation of the skin and unpleasant sensation, particularly when young children are concerned. Implantable systems would by all means be more suitable. However, their application is not indicated in the actual phase of the research.

DISCUSSION

Preliminary results of electrophysiological analyses are indicative of the changes in proprioceptive reflex mechanisms and preserved organization at the highest levels of the sensorimotor integration. At the same time a variety of the patterns of EMG activity of the paravertebral muscles at movements of the trunk and load of the spine and various frequency spectra of the EMG of the paravertebral muscles in the area of the curve concavity and convexity were revealed. In the actual state of the research we cannot speak of the primary role of these changes in the development of IS, or explain mechanisms responsible for these changes. Yet, these preliminary results are indicative of a direct effect of the external control of contraction of the paravertebral muscles upon the decrease of the curve in IS. Impairment or improvement of the condition can be achieved within a relatively short period of time. This proves that the method has a strong effect on scoliotic deformities though via extraosseous mechanisms influenced by an additional inflow of information in the control of muscle contraction and the effect of these upon postural mechanisms, particularly those of the proprioceptive reflex system. Further investigations, confirmation of preliminary results and explanation of mechanisms under the effect of FES, the choice of the way of stimulation and optimal muscles or groups of muscles, are expected to achieve not only the improvement of the therapy approach but also the detection of mechanisms involved in the development of IS.

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