THE EFFECTS OF ELECTROMYOGRAPHIC BIOFEEDBACK (EMG-BFB) THERAPY ON THE CHARACTERISTICS OF STUTTERING

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Stuttering is an action-induced speech disorder with involuntary, audible, or silent repetitions or prolongations in the utterance of short speech elements (sounds, syllables) and words. The responsibility of the speech-language pathologist is to provide direct, early intervention for stuttering and to choose justifiable treatment procedures. In this study we measured different manifestations of stuttering before and after electromyographic biofeedback (EMG-BFB) therapy. The EMG-BFB includes the recording of the muscle activity from surface electrodes, observation of biological signals, and provoking specific changes in the framework of the muscles. The manifest area of stuttering was measured by means of 9 variables.The result shows differences in the structure of the manifestations at the beginning and at the end of the EMG-BFB therapy. Besides lower tension in the larynx muscles, frequency in speaking and reading, and duration of block, changes in the quality of speaking and reading were also noticed, which imposes the necessity for a different approach to the diagnostics and therapy of stuttering.

In the diagnosis and therapy of stuttering there are no satisfactory methods for measuring the fluency and manifestations of speech. Most often it is prescribed by differently defined mistakes in speech given in percents of mistakes per one hundred spoken words, measuring the emission duration and blocks or observing distracting movements of extremities or facial grimaces. In the stuttering diagnostics the most commonly used scales are the Iowa Scale for Rating Severity of Stuttering (Johnson, Darley & Spriesterbach 1963, Sherman, 1952) and the Stuttering Severity Instrument for Children and Adults (Riley, 1972). Yet there is still a necessity for an objective instrument in order to describe the severity of stuttering and all other concomitants.

The regulational systems in humans accept information, compare them to the agreed standards and decide on the amount and the direction in which a correction should be made in order to that it agree with the confirmed information (Guyton, 1986). This means that there is no possibility of any kind of regulation without feedback on the information, and that their abilities to generate error-free speech programs are disordered (Postma & Kolk, 1993). From the point of view of automatic regulation, speech is a very complex regulational system. In this context, stuttering can be observed as instability in the regulational system. Biofeedback is one of the procedures which helps us to make new feedback relations within the complex speech system and within the whole organism. During this procedure we use external technical tools for the observation of biological signals and procedures in order to induce changes within the system. The method that is most commonly used in practice is electromyographic biofeedback (EMG-BFB). It registers muscular potentials throughout different phases of speech and on different muscular clusters. The most interesting results are those obtained in the research of the relation of stuttering and EMG (Denny & Smith, 1992; Smith, Luschei, Denny, Wood, Hirano & Badylak, 1993). So far, all work and expe-

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rience has been based on the use of a standard EMG device and the analysis of the muscular potentials (Van Lieshout, Peters, Starkweather & Hulstijin, 1993; Smith et al., 1993). The standard EMG is a method of registration of action potentials, so that latent pathological changes of the nervous muscular apparatus may be detected. When acoustically reviewing it, we analyze the intensity, duration, regularity of appearance, and frequency of the tone repetition. It is completed by visual analysis by the type, intensity, duration, frequency, regularity, and the constancy of occurrence (Licul, 1981).

The standard EMG technique is a conventional method, somewhat complicated in the analysis of registered subjects, with quick changes and small voltages (Van Riper, 1973). Novosel and Ribić (1984, 1986) designed the prototype of the device for EMG biofeedback RN 48. The program's function is to help in the regulation of prephonatorial, phonatorial, and postphonatorial laryngeal muscle tension combined with the relaxation and self-suggestion used during the whole therapy. It has been suggested that laryngeal muscle tension is an important factor in stuttering (Van Riper, 1971), and EMG sensors distinguish stuttering from fluent speech (Schwartz, 1974). Placing electrodes on the external area of the larynx, Hanna, Wilfling and McNeill (1975); Kalotkin, Manschreck and O'Brien (1979); and Lieshout et al., (1993) succeeded in reducing stuttering after only a few EMG-BFB treatments. Therefore, it has been proposed that the reduction of laryngeal muscle tension should reduce stuttering.

Knowing how to use EMG to detect the muscular activity of the sound-speech system, as well as alterations relevant for the explanation of certain events in the speech dynamics, is extremely valuable. The observed changes, - i.e., increased laryngeal muscular tensions in stutterers before or during speech and the duration of the tension, type, or amplitude of muscular potentials - are all relevant to the explanation of the phenomenon of verbal non-fluency and help indicate more efficient therapy. The purpose of this study was to follow different manifestations of stuttering before and after the EMG-BFB therapy, which includes the recording of the muscle activity and provoking specific changes in the framework of the observed muscle or group of muscles.

METHOD

Subjects

Sixty-eight subjects clinically diagnosed as stutterers, without any other significant difficulties in development, participated in the study. The mean age of the subjects was 20.3 (SD 9.6), with a range from 10 and 43 years. The group included 21 female and 47 male stutterers. The majority of the subjects had gone through some other therapy before, but they were being subjected to the EMG-BFB twelve-day therapy for the first time.

Methods

The measuring instruments were designed for a number of purposes, such as collecting anamnestic, autobiographical, and speech status data, observation of the accompanying phenomena, adaptation to stuttering, consistency of stuttering, subject's attitude towards stuttering, and a profile of emotions for each subject. Besides the subjective estimation of the stuttering and the placement of the block, the EMG-BFB method was used in order to investigate the effects of the reduction of laryngeal muscle tension on fluency of speech.

EMG-BFB contains a program for graphical data analysis and presentation of the integrational muscular larynx activities using the RN-48 instrument. The method enables the patient to monitor and willingly regulate and maintain muscle tension through all phases of speech. When the patients have established speech, everything they have learned during the therapy has to be practiced in everyday communication. Speaking with strangers, asking for information, telephoning, etc. were also parts of the therapy. Since many tensions are subconscious, many people cannot reduce them and influence the fluency of the speech. Thus, the EMG-BFB method demands a cooperative collocutor who must be prepared and persistent in mastering this complex and very effective technique.

During the EMG-BFB therapy, increased laryngeal muscle tension was observed immediately before speech (LMTS) and reading (LMTR). We measured the total frequency of repetition and prolongation of sounds and syllables in speech and reading (RTFS), total duration (RTDS), and total physical concomitant (RTPCS) according to Riley's Stuttering Severity Instrument, as well as the time of a hundred spoken (RTIME) and read (READING) words, the number of nouns beginning with a given letter written in two minutes (NRWN2), and the number of nouns beginning with a given sound spoken in two minutes (NRCN2).

All the variable values were measured before and after the therapy. The data were recorded on video and audio tapes.

RESULTS

The basic statistical parameters, mean, standard deviation, and minimum and maximum results are shown in Table 1.

Table 2. *Eigenvalue (hotelling) at initial measuring.*

	EIGENVALUE	PCT. OF VAR	CUM. PCT
1	3.27	36.4	36.4
2	1.46	16.2	52.5
3	1.29	14.3	66.9 ← *last counted eigenvalue*
4	0.86	9.5	76.4
5	0.64	7.1	83.5
6	0.49	5.5	89.0
7	0.40	4.4	93.4
8	0.33	3.7	97.1
9	0.26	2.9	100.0

Table 3. *Principal component analysis with variable communality at initial measuring*

VARIABLE	F1	F2	F3	COMMUNALITY
LMTS	0.55	0.21	-0.62	0.73
LMTR	0.42	0.28	-0.69	0.73
RTFS	0.81	0.09	0.27	0.73
RTDS	0.77	-0.08	0.22	0.64
RTPCS	0.59	0.29	0.03	0.45
RTIME	0.68	0.01	0.24	0.52
READING	0.71	0.03	0.29	0.59
NRWN2	0.12	0.87	0.15	0.79
NRCN2	-0.45	0.68	0.28	0.74

Table 1. *Basic statistical parametars of both examinations*

	FIRST EXAMINATION				SECOND EXAMINATION			
VARIABLES	MEAN	STD.DEV	MIN	MAX	MEAN	STD.DEV	MIN	MAX
LMTS	34.84	33.26	2	166	8.76	5.69	2	42
LMTR	26.88	25.36	4	135	6.84	4.77	1	23
RTFS	14.26	3.45	3	18	3.10	4.82	0	16
RTDS	2.81	1.19	1	5	0.54	0.89	0	4
RTPCS	8.06	4.26	2	18	1.04	1.67	0	7
RTIME	110.74	62.68	52	400	73.93	15.88	46	125
READING	74.03	50.40	38	267	51.31	12.55	11	79
NRWN2	13.44	4.87	5	26	16.51	5.34	8	32
NRCN2	14.59	5.24	5	29	20.69	6.90	10	42

Three characteristic roots explaining 67% of the common variability were obtained by factor analysis (method of principal components, oblimin rotation) of the nine examined variables in the first examination (Table 2). It is worth consideration that all variables reached communalities (RTPCS,0.45 to NRWN2, 0.79), which shows their homogeneity (Table 3).

The matrices of pattern and structure of the first examination are shown in Table 4. The two matrices have similar structures of variable projections and can be analyzed simultaneously. The first factor consists of 5 variables measuring the frequency of stuttering while speaking and reading, the duration of the longest blocks, and observable physical concomitants. The structure of the second factor was determined by writing and counting the nouns begining with a given letter or sound, while the third factor was defined by the variables of larynx muscle tension while speaking and reading.

The factor correlation matrix shows only one significant correlation of -0.33 ($p<0.05$) between the first and the third isolated factors (Table 5).

The share of the three isolated factors processed by factor analysis of the nine examined variables in the second examination, in the mutual variance is 70%, more than in the first examination (Table 6). The applied variables again show us (Table 7) communalities rating from 0.46 (RTPCS, RTIME) to 0.85 (NRWN2). The results of the factor analysis at the end of the therapy show differences in factor structure (Table 8). Variables of total physical concomi-

Table 4. Pattern and structure matrices at initial measuring

	PATTERN MATRIX			STRUCTURE MATRIX		
VARIABLE	F1	F2	F3	F1	F2	F3
LMTS	0.07	-0.07	-0.83	0.34	-0.08	-0.85
LMTR	-0.09	-0.01	-0.88	0.20	0.01	-0.85
RTFS	0.86	0.04	-0.01	0.85	-0.06	-0.29
RTDS	0.78	-0.13	0.02	0.79	-0.23	-0.24
RTPCS	0.54	0.20	-0.24	0.59	0.13	-0.42
RTIME	0.73	-0.02	0.04	0.72	-0.11	-0.20
READING	0.78	-0.05	0.09	0.76	-0.15	-0.17
NRWN2	0.06	0.89	-0.09	-0.02	0.88	-0.11
NRCN2	-0.14	0.79	0.19	-0.30	0.81	0.24

Table 5. Factor correlation matrix at initial measuring.

	F1	F2	F3
F1	1.00		
F2	-0.12	1.00	
F3	-0.33	-0.02	1.00

Table 6. Eigenvalue (hotelling) at final measuring

	EIGENVALUE	PCT. OF VAR.	KUM. %	
1	3.39	37.7	37.7	
2	1.77	19.7	57.4	
3	1.09	12.1	69.5	← *last counted eigenalue*
4	0.75	8.4	77.8	
5	0.71	7.9	85.7	
6	0.47	5.2	90.9	
7	0.42	4.6	95.9	
8	0.28	3.1	98.7	
9	0.12	1.3	100.0	

Table 7. Principal components analysis with variables communality at final measuring

VARIABLE	F1	F2	F3	COMMUNALITY
LMTS	0.49	-0.08	0.77	0.84
LMTR	0.66	-0.06	0.46	0.65
RTFS	0.87	0.13	-0.28	0.84
RTDS	0.81	0.26	-0.26	0.78
RTPCS	0.68	-0.03	-0.00	0.46
RTIME	0.67	0.09	0.02	0.46
READING	0.61	-0.25	-0.34	0.55
NRWN2	0.04	0.92	-0.03	0.85
NRCN2	-0.20	0.87	0.15	0.82

tant (RTPCS) are in initial measuring part of first factor which is consisted of stuttering frequency variables, but at final measurment form part of the third factor, which is characterized by laryngeal muscle tension. This time the factor correlation matrix did not show any significant correlations between isolated factors (Table 9).

According to the results, it can be observed that after the therapy, when laryngeal muscle tension was lowered, there is no correlation between frequency of stuttering or speaking, reading, and writing with laryngeal muscle tension. All changes shown by the results were registered before and after EMG-BFB therapy. They indicate that people with the lower tension in the larynx muscles can successfully improve frequency in speaking and reading and duration of stoppage, as well as the changes in the quality of their speaking and reading.

The differences between the variables before and after the application of the transformational procedures have been calculated by t-test for dependent samples. The results a given in Table 10. The examinations and comparisons of means and the standard deviations of the results revealed significant differences (p<0.05) between the measurements before and after the therapy. All measured variables, except for the number of written nouns to the given letter (NRWN2), whose differences between the first and second measuring are not statistically significant, show the same characteristics.

This result could have been expected, because stutterers do not have problems in writing nor in understanding a written

Table 8. Pattern and structure matrices at final measuring

	PATTERN MATRIX			STRUCTURE MATRIX		
VARIABLE	F1	F2	F3	F1	F2	F3
LMTS	-0.09	-0.13	0.83	0.08	-0.18	0.82
LMTR	0.02	-0.06	0.85	0.19	0.01	0.85
RTFS	0.88	0.08	0.11	0.90	0.05	0.28
RTDS	0.89	0.19	-0.03	0.88	0.16	0.14
RTPCS	0.49	-0.01	0.51	0.60	-0.06	0.61
RTIME	0.68	0.02	0.02	0.69	0.00	0.16
READING	0.68	-0.33	-0.14	0.66	-0.34	0.02
NRWN2	0.13	0.90	-0.01	0.11	0.90	-0.04
NRCN2	-0.08	0.88	0.08	-0.13	0.89	-0.15

Table 9. Factor correlation matrix at final measuring

	F1	F2	F3
F1	1.00		
F2	-0.05	1.00	
F3	-0.19	-0.02	1.00

Table 10. T-Test for dependent variables before and after the therapy.

	FIRST EXAMINATION		SECOND EXAMINATION						
VARIABLE	MEAN	STD.DEV	MEAN	STD.DEV	DIFF.	STD.DEV. DIFF	t	df	p
LMTS	34.84	33.26	8.76	5.69	26.07	31.95	6.73	67	0.00
LMTR	26.88	25.36	6.84	4.77	20.04	24.61	6.72	67	0.00
RTFS	14.26	3.45	3.10	4.82	11.16	4.39	20.98	67	0.00
RTDS	2.81	1.19	0.54	0.89	2.26	1.33	13.99	67	0.00
RTPCS	8.06	4.26	1.04	1.67	7.01	3.93	14.70	67	0.00
RTIME	110.74	62.68	73.93	15.88	36.81	57.09	5.32	67	0.00
READING	74.03	50.40	51.31	12.55	22.72	48.43	3.87	67	0.00
NRWN2	13.44	4.87	16.51	5.34	-3.07	3.94	-6.42	67	0.06
NRCN2	14.59	5.24	20.69	6.90	-6.10	5.32	-9.46	67	0.00

Table 11. Total overall score on Riley's SSI before and after the EMG-BFB therapy

TOTAL OVERALL SCORE (RILEY)	BEFORE THERAPY	AFTER THERAPY	SEVERITY
0-5	0	48	Very Mild
6-15	6	13	Mild
16-23	25	6	Moderate
24-30	17	1	Severe
31-45	20	0	Very Severe

text, but in expression. So it seems that the variable NRWN2 in this system shows some other information.

Table 11. clearly shows that the subjects belonged to the categories of moderate, intense, and very intense stuttering before the therapy. After the therapy, over 80% of the subjects displayed showed the characteristics of very low and low stuttering.

DISCUSSION

EMG-BFB (Novosel, 1990) has been shown to be an effective tool in the treatment of stuttering and, along with the education of patients, it could successfully improve the fluency of speech. The advantage of EMG-BFB is the involvement of the patient in a rehabilitation process in which he/she can voluntarily influence the laryngeal muscle tension based on information about their muscles that they can see on the monitor.

The investigation showed that the structure of stuttering manifestations was different before and after the EMG-BFB therapy. The subjects apperienced not only lower tension in the larynx muscles, lower frequency of stuttering in speaking and reading, and shorter duration of block, but also the changes in the quality of speaking and reading have been noticed.

Significant differences in terms of the laryngeal muscle tension in speaking and reading have been confirmed as well. It is indisputable that the changes and inner turmoils in stuttering persons, while speaking and reading, influence the larynx, which does not mean that they do not influence the other systems of the organism i.e., pulse, blood pressure, and intensified secretion of adrenal gland muscles (Novosel, 1990)). Significantly increased laryngeal muscle tension was in correlated with the frequency of stuttering (0.27, $p<0.05$), duration of blocks (0.23) and physical concomitants (0.28), as well as the intensity of stuttering (0.33).

The tension of the muscles was considerably reduced after the therapy, which resulted in more fluent speech. This all leads to the idea that the measurment of laryngeal muscle tension could be used as a diagnostic tool as well as for measuring rehabilitation efficiency.

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