

Hardware-software medical rehabilitation complex for vertebral diseases patients.

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Abstract

The distinctive feature of modern medical rehabilitation procedures is a high information level of diagnostic and therapeutic techniques, new diagnostic tools for external manipulation with a human body (rehabilitation equipment, hardware – software complexes and so on) based on the most advanced cybernetic and electronic microtechnology methodologies, programming etc. All of those systems are focused on accurate dosing parameters provision, maintaining of its values in terms of patient's physiological characteristics variability, and so on.

So called biofeedback complex plays the most important role in all these systems. Its purpose is to aim development and improvement processes and self-regulation mechanisms for physiological functions in various pathological conditions. Such systems in Ukrainian rehabilitation facilities are still rare, but our experience proved their practice effectiveness and promoted our own promising rehabilitation method.

The aim of our investigation is to research and analyze multi-functional hardware-software system EN-TreeM in vertebral diseases patients' rehabilitation course.

According the results of our investigation we can make a conclusion, that single session kinesiotherapy effect on musculoskeletal system disorders for patients of both sexes is characterized by muscle strength increase and endurance. Kinesiotherapy stimulating effect on the human body improves the functional state of the neuromuscular system. Qualitative characteristics of strength value for female and male patients as a result of rehabilitation session increased by an average of 1 (95% BI 0; 2) kgs ($p < 0.05$); muscle endurance for female patients varied by an average of 2 (95% BI 1; 3), for male patients 1 (95% BI 0, 4) ($p < 0.05$). Rehabilitation course showed an increase muscular endurance of male patients by an average of 4 (95% CI 2, 6), statistically significant differences for female patients' endurance parameters before and after were not recorded.

Miographical studies have shown that the value of chronaxia by kinesiotherapy rate remained stable for female and male patients, varied by 70 ± 16 (95% BI 60; 123) ms. This shows the lability of muscle tone for male ones due to the high proportion of striated muscle.

Clinical observations showed good kinesiotherapy procedures tolerability and lack of adverse reactions. All patients reported pain reduction or initial pain relief. The improvement occurred even after the first procedure. When rehabilitation course was finished, there was significant reduction in pain and inflammation and even complete relief of pain and destructive inflammatory responses. Range of motion was increased. Vertebrogenic pain relief was observed after 2-5 days of treatment, radicular pain relief was observed after 4-6 days of treatment.

Kinesiotherapy and cryotherapy usage in treatment of musculoskeletal system disorders for patients of both sexes are well tolerated. There are no side effects, such treatment promotes inflammation regression, reduces the severity of pain and reflex tonic syndromes.

Key words:

Hardware-software, medical rehabilitation, vertebral diseases

Modern aspects of the musculoskeletal disorders patients' rehabilitation program are examined in the article. Obtained results are analyzed, vertebrogenic patients' rehabilitation kinesiotherapeutic program implementation is recommended. The conclusion about further and extended implementation and practice research necessity in this area is drawn.

Preface

The distinctive feature of modern medical rehabilitation procedures is a high information level of diagnostic and therapeutic techniques, new diagnostic tools for external manipulation with a human body (rehabilitation equipment, hardware – software complexes and so on) based on the

most advanced cybernetic and electronic microtechnology methodologies, programming etc.

All of those systems are focused on accurate dosing parameters provision, maintaining of its values in terms of patient's physiological characteristics variability, and so on.

So called biofeedback complex plays the most important role in all these systems. Its purpose is to aim development and improvement processes and self-regulation mechanisms for physiological functions in various pathological conditions. Such systems in Ukrainian rehabilitation facilities are still rare, but our experience proved their practice effectiveness and promoted our own promising rehabilitation method.

The aim of our investigation

To research and analyze multi-functional hardware-software system EN-TreeM in vertebral diseases patients' rehabilitation course.

Methods and materials

265 vertebral patients took rehabilitation treatment part in the research at State Institution "Scientific practical medical rehabilitating diagnostic centre of the ministry of health of Ukraine" (M 42.0 – M 54 за МКБ-10) at recrudescence stage. However, during clinical treatment according to medical protocol for dorsopathy patients treatment (Ministry of health of Ukraine order #487 from 17.08.07) patients were treated by our original methodology. 73 male patients (27.2%) aged 52 ± 1.6 and 196 female patients (72.8%) aged 53 ± 1.8 took part in the research (table 1).

Table 1. Patients' general characteristics

Sex	Age, years (Me \pm m)	Number of patients, n	Number of rehabilitation sessions, n
Male	53 ± 1.8	73	1656
Female	52 ± 1.6	196	2461
Total, n		269	4117

Visual inspection, survey and analysis of the patients for the presence of current state complaints provided to allocate dorsopathy patients (178 patients of age 51 ± 1.7 years) and ple-

xopathy ones (91 patients of age 55 ± 1.6 years). Medical characteristics according to patients' diagnosis are presented in table 2.

Table 2. Medical characteristics according to patients' diagnosis

Patient's diagnosis	Age, years (Me \pm m)	Number of patients, n	Number of rehabilitation sessions, n
Dorsopathy	51 ± 1.7	178	3134
Plexopathy	55 ± 1.6	91	983
Total, n		269	4117

Dorsopathy patients suffered of muscle tonic pain syndrome, but plexopathy patients, besides the aforementioned, suffered of cornucopia syndrome. Patients complained of lumbus pains, movement limitation and muscle tension were very intensive during body turning or movement. Patients of both groups were treated according to standard therapy, which included non-steroidal anti-inflammatory, vitamin, miorelaxing and chondroprotective therapy.

To assess patients' conditions before and after the treatment following measures were carried out: medical history and objective examination, anthropometric data collection.

Assessment of the neuromuscular system took place according to electromyography (EMG).

The following investigation methods were used: innervation research, anxiety test, rheobase and chronaxie determination, the value of useful time curve $1/t$.

The right and left forearm muscles, round pronator (*M. pronator teres*), which prones forearm and participates in its bending, were objects of miographical study. *N. Medianus* of C6-C7 was innervated. Also, right and left limb femoris, femoral muscle (*M. femoralis*), which is involved in its bending, were object of the study. *N. Femoralis* of L5-S1 was innervated.

The innervation reaction was compared for two symmetrical contralateral muscles or muscle groups, innervation was probably interrupted for one of them.

The study started with a determination of muscle motor point. The motor point were determined using palpating or small electrode (at constant electric current value), the second electrode was imposed proximally. Then the second pair of electrodes was overlapped on the other study muscle at the same point as stated by the symmetrical muscle.

Once the motor point was localized, amperage was increased as long as no reduction occurred for both muscles, visualization of muscle contraction was conducted, which was observed with the naked eye, in case when muscle contraction was not observed. When the reduction was observed, measure of muscle innervation was estimated.

During conducting tests we determined the extent of excitability in muscle degeneration. Muscle stimulation was performed and response to muscle stimulation was determined. The electrode was moving until excitation process involving different muscle fibers started. Level of excitability was determined. Normal muscle contraction innervation should take at least one minute.

As a result of miographical study, rheobase, chronaxie, useful time curve I/t values were determined.

For this study, two superimposed pairs of electrodes were used. Slight muscle stimulation was performed to compare the answers of researched and contralateral muscle responses. One electrode was placed in the muscle motor point and the other was placed proximally. The second pair of electrodes was placed on the other muscle. Electrical amperage was stepped up slowly to obtain good visible muscle response.

Rheobase is a minimal amperage level, required to obtain a minimum reduction in rectangular pulses with a duration of more than 100 ms. If current is below its rheobase value, there would be no muscle contraction, even with infinite pulse duration [19].

In case of rheobase denervation occurred, current value is reduced, but rheobase doesn't remain constant (for corresponding rheobase muscle fibers).

During reinnervation process, rheobase increases up to 2-3 times of normal rheobase value. Then rheobase is reduced, it barely exceeds the normal value. We should pay attention to the quality of muscle contraction. Response to stimulation may be clear and sharp, indicating the involvement of all fibers in the opposite physiological reduction at which the duty motor units.

If denervation reduction is slow and has a worm-like character, this situation corresponds to the linear and asynchronous stimulation of galvanotonic low muscle fibers.

Chronaxia is a rectangular pulse duration, sufficient to cause minimal reduction at a current equal to double the rheobase. On the curve I/t chronaxia corresponds to a reduction of the minimum energy: $Q = I \times t$.

Minimum reduction is a reduction, noticeable only on the skin surface. Healthy muscles chronaxia level lays between 60 and 700 ms. For denervated muscle, chronaxia level may rise about 200 times (in this case chronaxia level is a characterizing value for any muscle fiber).

Useful time is a pulse duration when the curve departs from the asymptotic plateau (pulse duration lays over 100-200 ms to 1000 ms). This value determines the minimum useful time required to induce pathological fibers. This factor determined the shape of the pulse and its rise time at which the election is achieved by stimulation pathologically innervated fibers with minimal amperage. You should keep in mind that by stimulating muscle fibers that normally innervated, we encourage appropriate nerve fibers. The results obtained from fully or partially denervated muscles correspond to muscle fibers electrical parameters, or to a combination of nerve and muscle fibers. Test results were taken down to out-patient medical record and special computer log file.

With EMG minimum time sufficient to current defined at twice the rheobase called pulse excitation. This is a chronaxia indicator.

This indicator characterizes the level of emergence excitement: the higher the intensity and speed of working muscle, the less is chronaxia. Chronaxia definition as temporary excitability index used to characterize parameter for patient's supporting-motor system.

During the study, 538 chronaxia investigations were conducted. Miographical studies were carried out before and after rehabilitation course, using the miography apparatus "MYOMED 932".

Kinesiotherapy was performed on the simulator EN-TreeM ("Enraf-Nonius B.V.", Netherlands) with biofeedback feature. Biofeedback is a technology that includes physiological procedures when a patient is connected to an external feedback circuit, organized primarily through microprocessor or computer technology presented information on the status and change certain own physiological processes. Therapy for this kind of technology is continuously monitored in real time. Certain physiological parameters and conscious are controlled via multimedia, gaming and other methods in a given range of values. The example of such kind of equipment is the gadget, developed by Enraf Nonius (Netherlands) multi rehabilitation training EN-TreeM, which allows training almost any human monarthric and complex movement. Thanks to the wide range of loads (from 0.5 kg to 72 kg) medical personal is able to deal with both power and locomotor exercises. In physical therapy and rehabilitation, objective characterization of functional musculoskeletal rights abilities is very important. Often this information is needed for a variety of functional studies on the effectiveness of different methods of rehabilitation for reporting

on the effectiveness of a course of therapy and in other cases. This simulator allows to measure and store in memory information about the patient's motion range, movement speed, functional development and other parameters. These parameters make possible to describe patients' functional abilities in quantitative terms. To analyze the study results, provided special software package was used. That allows to develop a preliminary assessment and to select the optimal individual therapy. To stimulate the patient during therapy and rehabilitation period, training provided choice of different feedback screen pages. It is possible to set the aim of therapy (range of motion or effort development) and offer to patient the best of visual feedback.

Obtained results are analyzed in the statistical software packages Statistica 5.5 (StatSoft. Inc., 1999), Statistica Neural Networks 4.0C (StatSoft. Inc., 1999), MedStat 2004.

Obtained results and discussions.

The results revealed that the initial values of power and endurance for male and female patients are significantly differed ($p < 0.05$). For female patients, the average of the initial force constituted 22.0 ± 0.9 (95% VI 20-24) kg, for male patients 44.0 ± 1.5 (95% VI 40-46) kg. Muscular endurance for female patients during the course amounted to 32.5 ± 2.9 (95% VI 30-40) on average, for male patients 45.0 ± 4.1 (95% VI 45-50) correspondingly (Table 3).

Table 3. Muscle power and endurance on the first day of rehabilitation course, (Me \pm m)

Research	Male patients, n=73	Female patients, n=196
Muscle power, kgf	44.0 ± 1.5	22.0 ± 0.9
Muscle endurance, s	45.0 ± 4.1	32.5 ± 2.7

The impact of a single rehabilitation session was characterized by an increase in muscle strength level and endurance for patients of both sexes. The value and strength of female and male patients increased by an average of 1 (95% VI 0-2) kgf ($p < 0.05$). Muscular endurance for female patients varied by an average of 2 (95% BI 1-3), for male patients – of 1 (95% VI 0-4), ($p < 0.05$).

These change is the evidence of kinesitherapeutic stimulating effect on the human body, which improves the functional state of the neuromuscular system.

The evidences of impact on rehabilitation strength values for female patients are absent, but are obvious for male patients (average incensement of 45, 5 \pm 2, 7 ($p > 0.05$)) (Table. 4).

Table 4. Muscle power and endurance on the 20th day of rehabilitation course, (Me \pm m)

Research	Male patients, n=73	Female patients, n=196
Muscle power, kgf	45.5 ± 2.7	22.5 ± 0.9
Muscle endurance, s	50.0 ± 1.7	33.2 ± 1.6

After rehabilitation course male patients' endurance increased by an average of 4 (95% CI 2-6) and achieved 50 ± 1.7 (95% VI 49-55), ($p < 0.05$), but female patients endurance practically remained unchanged 33.2 ± 1.6 (95% VI 26-47), ($p > 0.05$).

During the study, chronaxia was investigated too. Chronaxia output values for female patients achieved 210 ± 42 (95% BI 180-480) ms, but after the kinesitherapy course ± 46 (95% BI 150-400) ms, these values are statistically identical ($p > 0.05$) (Table. 5).

Table 5. Chronaxia values dynamics as a result of rehabilitation course (Me \pm m)

Day of rehabilitation period	Chronaxia, ms	
	Male patients, n=73	Female patients, n=196
1 st day	200 ± 35	210 ± 42
20 th day	130 ± 61	200 ± 46

For male patients, the average chronaxia value before kinesitherapy course was 200 ± 35 (95% CI 150-280) ms, but after the course it was 130 ± 61 (95% CI 100-300) ms ($p < 0.05$). Thus, rehabilitation course affected the only male patients' values.

Clinical observations have shown good kinesitherapeutic tolerability and absence of adverse reactions. All patients reported pain reduction and performed their exercise easily. The improvement was discovered even after the first procedure.

When rehabilitation course was complete, there was significant reduction of pain. Inflammation and pain were minimized and even completely removed. Destructive inflammatory responses were relieved and even absent. Motion range increased significantly. Vertebrogenic pain relief was achieved in 2-5 days, radicular pain relief was achieved in 4-6 days. Assessment of pain intensity was carried out using the Verbal Descriptor Scale - VDS (Gaston-Johansson F., Albert M., Fagan E. et al., 1990) before and after completion of rehabilitation course (Table 6).

Table 6. Mean values of pain intensity by VDS scale, before and after kinesitherapy course, (Me \pm m).

Day of rehabilitation period	Pain intensity, points	
	Male patients, n=73	Female patients, n=196
1 st day	4.6 \pm 1.6	4.2 \pm 1.0
20 th day	2.1 \pm 0.8	1.8 \pm 0.4

Patients' clinical manifestations in 1st day of kinesitherapy: pain syndrome – 260 patients (97%), feet dorsum numbness – 182 patients (67.5%), weak toe extension – 60 patients (22.5%), lameness – 54 patients (20%), reduced Achilles reflex – 25 patients (9%).

Patients' treatment quality criteria in case of musculoskeletal system disorders:

1. Pain reduction or disappearance.
2. Radicular pain and symptoms reduction or disappearance.
3. Increase motion range in the affected body part.
4. Health improvement.
5. Clinical recovery or improvement.

As a result of treatment 100% of dorsopathy and plexopathy patients were discharged with health improvement. There was a marked decrease in pain level, feet dorsum numbness disappeared. Number of patients suffered of weak toe extension, lameness and Achilles reflexes were minimized ($p < 0.05$).

Health worsening or side effects and complications during the procedures weren't observed.

Conclusions

1. Single session kinesitherapy effect on musculoskeletal system disorders for patients of both sexes is characterized by muscle strength increase and endurance. Kinesitherapy stimulating effect on the human body improves the functional state of the neuromuscular system. Qualitative characteristics of strength value for female and male patients as a result of rehabilitation session increased by an average of 1 (95% BI 0; 2) kgs ($p < 0.05$); muscle endurance for female patients varied by an average of 2 (95% BI 1; 3), for male patients 1 (95% BI 0, 4) ($p < 0.05$). Rehabilitation course showed an increase muscular endurance of male patients by an average of 4 (95% CI 2, 6), statistically significant differences for female patients' endurance parameters before and after were recorded.

2. Miographical studies have shown that the value of chronaxia by kinesitherapy rate remained stable for female and male patients, varied by 70 ± 16 (95% VI 60; 123) ms. This shows the lability of muscle tone for male ones due to the high proportion of striated muscle.

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3. Clinical observations showed good kinesitherapy procedures tolerability and lack of adverse reactions. All patients reported pain reduction or initial pain relief. The improvement occurred even after the first procedure. When rehabilitation course was finished, there was significant reduction in pain and inflammation and even complete relief of pain and destructive inflammatory responses. Range of motion was increased. Vertebrogenic pain relief was observed after 2-5 days of treatment, radicular pain relief was observed after 4-6 days of treatment.

4. Kinesitherapy and cryotherapy in treatment of musculoskeletal system disorders for patients of both sexes

are well tolerated. There are no side effects, such treatment promotes inflammation regression, reduces the severity of pain and reflex tonic syndromes.

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