METHOD AND DEVICE FOR IDENTIFYING, MEASURING AND ANALYZING ABNORMAL NEUROLOGICAL RESPONSES

The objective of the invention is a method and a device for identifying, measuring and analyzing abnormal neurological responses. In the method in accordance with the invention neurological diseases, pain, fatigue, poor working ability and/or activation and/or symptoms connected with those are estimated by measuring signals produced by muscles and by analyzing signals with nonlinear calculation methods. The device in accordance with the invention comprises sensors to be placed in the body or on the body surface for measuring signals produced by muscles, a signal analyzing device for analyzing signals with nonlinear calculation methods and a feedback device for giving feedback.
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METHOD AND DEVICE FOR IDENTIFYING, MEASURING AND ANALYZING ABNORMAL NEUROLOGICAL RESPONSES

The present invention relates to a method and device for identifying, measuring and analyzing abnormal neurological responses.

Abnormal neurological responses are caused among other things by some neurological diseases, pains, fatigue, problems in power producing ability or in activeness.

Electric signal of muscles i.e. Electromyography (EMG) measured from the skin surface describes activation and functioning of muscle cells/motor units during the contraction of a skeletal muscle. It is commonly known that by means of an EMG-signal it is possible to measure activity levels of muscles and from those calculate various quantities describing the functioning of muscles and the body. EMG-signal is usually measured through electrodes placed on the skin overlying muscles.

As muscle power increases, the central nervous system recruits in increasing amount muscle cells/motor units in order the muscle power to achieve the functional level to enable the growing mechanical performance. The accuracy of a mechanical performance and the power supply of a muscle function under a complex response system, in which besides the central nervous system also the golgi tendon organs and muscle bundles with their response systems take part.

Experience of muscles and the size of muscle cells, as well as activeness of the central nervous system have influence on the muscle power supply. The energy transform of a muscle (e.g. the function of mitochondria) and the distribution of muscle cell types, which depend on the degree of mechanic experience of the muscle, have effect for their part on endurance property of muscle cells.

As a performance lasts longer and the skeletal muscle gets tired, its function changes in accordance with the energy transform and the muscle cell type / distribution (fast-twitch/slow-twitch). When tired the conduction velocity of action potential gets slower on the membrane of a muscle cell along with saturation of K+ and Na+ ion change and rerecruiting getting slower. In a powerful performance, leading to fatigue of the skeletal muscle the oxygen intake to energy production weakens and the cell acidifies as the result of accumulation of H+ ion concentration inside the cell. As the result the velocity of action potential wave on the muscle membrane gets slower being longer in time (= frequency gets lower).
Fatigue of a muscle is in accordance with current knowledge also the result of saturation of recruiting processes and response systems on central nervous system level. On central nervous system level as a muscle gets tired, the recruiting of muscle cells changes as the result of the influence of changes in function of the central nervous system and the response systems, in which case the function of motor units in the muscle synchronizes. As the result of this, the measured EMG-signal changes to be less complex and its frequency gets lower.

Typically, the EMG-signal of a healthy person is stochastic and even nonstationary / chaotic in some respect. In abnormal situations (e.g. pain, a disease of the central nervous system, Parkinson’s disease, lowering of activeness, chronic fatigue, depression) there occurs changes of motor control and its response systems on central nervous system level, which changes lead to decreasing of complexity of the EMG-signal. In diseases on central nervous system level, there are typically changes in the functions of neurotransmitters of the brain (e.g. dopamine in Parkinson’s disease and serotonin in depression) which partly change the motor firing system and also affect the functions of response systems disadvantageously.

EMG-signal is usually measured in two different ways depending on what kind of measuring accuracy or analysis of results are wanted or, on the other hand, what kind is the technical operating capacity of measuring equipment. The most versatile measuring and analyzing options are achieved by measuring EMG bi-polar as so-called RAW EMG-signal. By utilizing sufficiently high sampling frequency, for example 1000 – 10000 Hz it is possible to make analysis from a signal, precise enough for scientific research by means of FFT spectrum calculation. Equipment, measuring RAW signal has to possess great capacity of processing and great memory capacity. Another typical way of measuring is so-called averaging i.e. AVERAGE-EMG method, in which method the EMG-signal received from a muscle is first rectified and after that averaged by sliding 0,1 – 1 seconds window over the data area. Typically, loading of muscles is estimated, loading comparisons are made, activating rates and times of muscles are examined and so on by analyzing the AVERAGE-EMG-signal. Measuring of AVERAGE EMG-signal may in principle be made with a rather simple equipment.

Each EMG-signal forms a so-called profile, in which active and passive states of the measured muscle may be seen as changes in amplitude of the signal. In addition, the frequency spectrum of the signal contains information on the function of the muscle. Quantities describing the function of muscles among others are:
- muscle load and changes in it
- distribution of load on different muscles of the body
- the side-difference between two symmetrical muscles, when loading simultaneously with the same load
- activation order, activation times, reaction times and so on of muscles
- comparison of activation profiles of muscles in various states of a performance and on different test persons
- fatigue of muscles

In addition, from the shape, amplitude, frequency spectrum and changes in those of an EMG-signal it is possible to calculate plenty of other quantities to be monitored and controlled. The measured EMG-signals are transmitted typically either to be presented in real-time on a display device or signals are stored in file format for later examination and analyses.

It is commonly known that the performance level and the degree of fatigueness may be estimated by measuring and analyzing an EMG-signal produced by a muscle. In traditional EMG-analysis, data is studied using linear time-frequency level methods. One method of this kind has been described in US Patent 5,361,775 by Mega Elektroniikkka Oy, among other things, in which by a FFT- i.e. spectrum analysis made from an EMG-signal several quantities correlating with fatigue of a muscle are able to be received. Fatigue of a muscle may be seen in power spectrum of an EMG-signal among other things as lowering of mean-frequency and, on the other hand, as rising of averaged EMG-activity level.

In practical situations, e.g. in a dynamic contraction, the received EMG-surface signal is unstationary, in which case properties and character of signal variation is not possible to be described sufficiently in traditional manners. Linear methods such as FFT-analysis may be applied limited for analysing of an EMG-signal while a linear analysis of an unstationary and stochastic signal averages the result and therefore a part of the real information from the signal is lost. Symptoms, which may not be perceived by traditional methods from EMG, are e.g. indication of pain response and response of changes caused by a signal of a neurological disease.

For analyzing of biosignals also nonlinear calculation methods may be used, additional information from which is not available using traditional methods. Nonlinear
methods are more applicable for analysis of stochastic EMG-signal. These kinds of algorithms are e.g. entropy, determinism, complexity-algorithms as well as entropic and fractal analyses. Several nonlinear calculation methods are commonly known. In literature e.g. RQA (=recurrence quantification analysis) and Lempel-Ziv complexity have been described. They are proved to be more applicable than linear algorithms for analyzing biosignals and therefore their use applied for diagnostic use and monitoring treatment of diseases is essentially better manner.

Next the Lempel-Ziv-complexity analysis and applying of it in measurements of biosignals is more closely described. Lempel-Ziv complexity C(n) searches periodicities and regularities in an EMG-signal. “Randomization” of a finite symbol line is therefore estimated by the algorithm.

A simple line 0000... has the complexity of 2, as 0 and the end part of zero have to be added to it by copying. Correspondingly the complexity of line 010101... is 3. In practice a digitized biosignal time series is processed into a symbol line by changing each sample of a time series e.g. to value 0 or 1 depending on whether the sample is bigger or smaller than the set threshold value, which may be, depending on calculation algorithm e.g. a mean value level. From a binary symbol line such produced e.g. 001111100011100011110011001110 as the result of the complexity analysis we get 0.01.1110.0001.1100001111.00110.0011110 i.e. c(n) = 7. The complexity of a symbol line is defined by a complexity counter c(n), which is received by calculating the number of different occurrence forms (words) in given symbol line. The number of these occurrence forms reveals the complexity or regularity of a signal. Usually received complexity values are normalized to 0-1 or 0-100%.

Another frequently used method is so-called RQA i.e. Recurrence Quantification Analysis, which has been developed especially for studying nonlinear systems. Eckmann was the first to publish RQA in 1987 and Webber introduced it in physiological studies in 1994. As RQA method is not dependent e.g. on the quantity of data or stationarity or statistical distribution of data content, RQA is well applicable in physiological systems, to which sudden changes, variations of levels, noise and so on originating in living organisms are often related. For example, in measuring fatigue the RQA method detects the starting moment faster and more sensitively than the FFT method. However, these analyses have not been used in disease grading in diagnostic sense.

The objective of the invention is to provide a method and a device for identifying, measuring and analyzing abnormal neurological responses, with the use of which it
is possible to identify easier, more objective and better than with present diagnostic methods phenomena of the central nervous system and the neuromuscular system and symptoms connected with abnormalities. In addition, the objective of the invention is to provide a method, which enables an early diagnosing of neurological diseases such as Parkinson's disease and utilizing in dosing medicine.

The objective of the invention is accomplished by a method and device, the characteristics of which are presented in the claims.

In the method in accordance with the invention neurological diseases, pains, fatigue, power producing ability and/or activeness and/or symptoms related to those are estimated by measuring signals produced by muscles and by analyzing signals with nonlinear calculation methods. Signals produced by muscles are in this context referred to as signals received by measuring in various ways from muscles and from their functioning. As earlier presented, there are several recognized nonlinear calculation methods in use, some of which are described earlier. In this paper, nonlinear calculation methods are not described very precise, and the method is not limited to any particular nonlinear calculation method but in the method, one or some nonlinear calculation methods may be used.

In an advantageous application of the invention, electrical signals of muscles are measured with a measuring device. In this case, measuring may be made non-invasive on the skin by means of different kinds of measuring sensors. The measuring device may be designed to be small by size, easy to handle, wearable and the processing of results may be realized by means of a computer or an embedded measuring system.

Advantageously electrical signals of active muscles are measured. In this case, parameters to be calculated from measuring signals may be defined fast and reliably. In an advantageous application of the invention, other signals produced by muscles than electrical signals may be measured with a measuring device on the skin by means of suitable measuring sensors. For example, acceleration, pressure and temperature are these kinds of signals. In neuromuscular diseases, tremor or functional disorders cause abnormal shapes of acceleration and pressure signals, which shapes may be identified in signal analysis phase. In addition, time-related stored image series or bit map describing the recruitment of different parts of muscles produced by means of magnetic resonance imaging (MRI) or ultrasound imaging may represent this kind of measuring manner. In these cases, sensors are not placed on the skin.
In the next additional application of the invention, the results received by the method are compared with the reference results stored in a database. In this case, differences between normal and abnormal result, changes and the stage of pathology may be defined.

In the next additional application of the invention, the results received by the method are transmitted to a user by means of a feedback device. The user may be e.g. a relative, a person doing or monitoring the study in a hospital, in a nursing home, at home with the person to be examined or in some other place. In this case, a dosing of medicine used for treating e.g. Parkinson’s disease or some other disease or for some other reason may be optimized in accordance with received results.

In the next additional application of the invention, the results received by the method are transmitted to the person examined by means of a personal feedback device. In this case the person him/herself may carry out the test or similar, and get feedback about changes in his/her activeness, development of motoric skills or need for dosing of medicine at home, and while needed get in touch with the person treating him/her.

Nonlinear analysis is more applicable than linear methods for analysis of biosignals due to stochastic and non-stationary character of signals. By means of analysis more information e.g. about pain reflection and disorders of the motoric and premotoric functioning model as well as from changes on cerebellum and corpus callosum level may be received. In this case, weakening of neurotransmitters such as dopamine and serotonin levels affect the complexity of an EMG-signal measured on a muscle and so-called fatigue changes are stronger than on a normal group.

Functioning of the central nervous system is commonly examined with measuring of so-called EEG-signal, which is carried out through electrodes placed on the scalp. EEG measures electrical functioning in the brain. For controlling the body and especially muscles also impulses going through the central and the peripheral nervous system are needed. EMG describes the control of the central nervous system and the motoric cortex more precise than EEG, while an EEG-signal is conducted through the scalp while measuring and EEG contains also responses related to control of vital functions and sense perception.

The nonlinear estimation method application of an EMG-signal enables e.g. following applications:

a) Objective estimation of pain
b) Estimation of decreasing of dopamine level of the brain typical of Parkinson's disease, which enables screening of persons in a risk group of Parkinson's disease (identifying of prestages), diagnosing of the disease and the follow-up of progression of the disease

c) By means of the method it is possible to time and dose the medical treatment of a patient of Parkinson's disease

d) Objective measuring of muscle fatigue

e) Follow-up of changes in activeness of the central nervous system due to various reasons (e.g. dementia, the Alzheimer disease, depression, chronic/acute fatigue)

f) Follow-up of development of motoric skills of the body and parts of it

When the results received by the method are compared to a database with reference results stored in it from patients suffering from neurological diseases and, on the other hand, from healthy test persons, it can be seen if the EMG-signal of the person examined has characteristics referring to a disease or deviation of calculation parameters from normal reference values.

Measurements made by the method and results from those may, while needed to be transmitted to the person who made the study, i.e. the user or to the person who was examined or to relatives by means of various display devices or corresponding feedback devices or to the person who was examined by means of a personal portable feedback device for possible further actions.

The method is applied by means of measuring system e.g. for diagnosing of pain and Parkinson's disease, for follow-up of treatment of Parkinson's disease, for objective measuring of muscle fatigue and in general for follow-up of changes in activeness of the central nervous system, in which method from the EMG-signals received from muscles by means of nonlinear calculation parameters connected with earlier mentioned diseases and symptoms are measured and compared if necessary to reference values gathered in database or to own earlier values concluding from changes or deviations proceeding of a disease, pain status or mentioned application action.

In an advantageous application of the invention, the method is utilized in diagnosing and treating of Parkinson's disease. Patients with Parkinson's disease suffer from changes in motoric control and its response system on the central nervous system
level, which changes are caused by changes of dopamine level. These changes may be seen as decreasing of complexity of the EMG-signal, which may be detected by a nonlinear analysis such as e.g. RQA. Based on this the follow-up of Parkinson’s disease patients or risk groups may be realized before outbreak of the disease.

EMG measured on the skin measures responses of motor units of a muscle, but utilizing nonlinear methods it is possible to analyze primitive mechanisms controlling muscle functioning of the central nervous system level. In neurological diseases, especially in Parkinson’s disease, these primitive controlling mechanisms are damaged and insufficient by function. Parkinson’s disease is the most important disease of so-called extrapyramidal system of the brain, the cause of which is unknown. In clinical diagnosis as the consequence of the disease has been stated among other things, that 60-80 % of the dopaminergic nigrostriatal pathways of the so-called substantia nigra located in the midbrain has been damaged or they are dysfunctional. The four main symptoms of Parkinson’s disease are resting tremor, rigidity (stiffness), hypokinesia (slowness of movements) and slowening of the correction reflex of balance. The most typical symptom is the resting tremor. The diagnosis of Parkinson’s disease is clinical, which is made on grounds of symptoms and the clinical detections of a physician. There are no objective methods as routine in clinical use. Before Parkinson’s disease has been clinically ascertained, the disease process itself has already proceeded far. By means of newer EMG analysis methods, it is possible to trace the disease already in the early phase of the disease. This would essentially help to make the diagnosis and to start the treatment earlier.

Next, the invention will be explained in more detail with reference to the accompanying figures, in which,

Figure 1 illustrates an example of an EMG-signal during contraction,

Figure 2a illustrates an EMG-signal of a healthy person, and

Figure 2b illustrates an EMG-signal of a Parkinson patient.

The use of nonlinear methods in examinations of Parkinson’s disease is based on the fact that the EMG-signal of Parkinson patients differs from the EMG of healthy persons. In figure 1 there is an example of so-called RAW EMG-signal during static contraction. An EMG-signal is a sum signal of individual action potentials caused by motor units in a muscle. Normal motoric control of a muscle causes always slight fading in an EMG-signal even visible in the figure as well as separate and oc-
casional spikes. Proportion of various deviations on a healthy person is quite small and no regularities may be found.

In figure 2a and 2b there are EMG measurements of three seconds duration on a healthy control person (figure 2a) and on a Parkinson patient (2b) presented. The measurements have been made during an isometric muscle contraction when the load of muscles remains as constant as possible on the average. Differences in recruiting of motor units on the healthy test person and on the Parkinson disease patient are visible with the eye. In the signal of the healthy person, some individual spikes higher than the variation of the base level may be seen. In the signal of the Parkinson patient, however, clearly more signal spikes stronger than the base level may be seen and they repeat more regularly and more organized than on the healthy test person. Increasing of strong spikes is caused by interruptions in motoric control. As the result of this, the motor units of the muscle function more synchronized among each other, which means growing of the signal level in the EMG-signal. In practice, the excessive synchronization of motor units means tremor of muscles and absence of fine motoric control necessary for even motion.

The diagnosis method of Parkinson’s disease is based on measuring made on a test person with an EMG-equipment and comparing of measuring results to comparison data in a database. Typically, an EMG-measurement is carried out on the muscles of the arm as the motoric control of arms is the most developed form of neuromuscular function. EMG-signal samples are taken with various standard motion course and power tests, in which case comparison of results with the database is possible. The motion courses to be tested are e.g. removing of an object of certain size and weight from one place to another along defined course. Along the course, the arm and the wrist must simultaneously e.g. clasp the object, move in horizontal and vertical directions as well as twist from one extreme position to another. In addition, the spontaneous EMG-responses of the muscle may also be analyzed and separate the healthy and the Parkinson patients on grounds of the measuring data by a normal every day muscle activation analysis.

The comparison database contains sample data both from the healthy and from the patients in various phases of Parkinson’s disease. In this case, the EMG-sample from a test person may give suggestions not only about the first symptoms of the disease but also about the proceeding degree of the disease. The results are normalized on grounds of data base comparison such that the proceeding degree may be categorized with a suitable scale.
The method may also be applied in dosing of medical treatment of Parkinson’s disease. The patient has an automatic dosing apparatus adjusted, which e.g. infuses medicine to the blood circulation or to the small intestine of the patient by means of estimation of the dopamine level based on EMG-measuring. EMG-measuring is made, for example, by means of a measuring wristband, which is easy to use and continuously functioning. A measuring wristband or other sensor is placed, for example, on the hand, feet and so on. Response from the measuring signal is analyzed at regular time intervals, for example every 5 min. When in the EMG-response, the analysis of which has been carried out by means of some nonlinear algorithms mentioned, has visible signs of falling of the dopamine level, the information is transmitted to the device the patient is carrying. The device may be a dosing pump or some other dozer of medicine, which has e.g. an alarm system for starting the dosing or for a dose of medicine to be taken internally. In more advanced models, syringing may start automatically through an invasive canule. It is also characteristic to Parkinson’s disease that the symptoms appear first on one limb, in which case by comparing signals both on the left and the right limb the ending of the influence of medicine may be anticipated in good time.

Overdosing of medicine may also cause adaptation of a patient to dopamine as the result of which the influence of medicine dose weakens. At the worst adaptation may facilitate the progression of the disease or cause premature death. By means of the device in accordance with the invention, a possible medicine overdosing may be avoided.

In an advantageous application of the invention pain response experienced by patients suffering from back pain in comparison with feelings of patients with similar by performance ability of muscles but with no pain. Condition of back muscles of patients with back problems has weakened and a part of patients suffers from pain also while loading muscles. Patients with back pain may be separated from healthy patients who have been through treatment/training by means of FFT method based on linear analysis, but the method does not separate individually pain patients. Identification of pain patients is successful while using the nonlinear RQA method and the method makes it possible to make a measurement from a measuring signal before rehabilitating exercise part and after it, whereas earlier the measurement had to be carried out with a linear method during the whole performance. In RQA method, reducing of % determinism has been proved to correlate with the decreasing feeling of pain of a patient.
In another advantageous application of the invention, the method is utilized in measuring of fatigue during dynamic motion. In the patent US 5,361,775 of Mega Elektroniikkka Oy a FFT analysis made from so-called RAW EMG-signal is described, by means of which analysis quantities correlating with muscle fatigue are calculated. The method has been proved functionable while measuring muscle fatigue during static load. FFT calculation gives suggestive results also during dynamic motion but muscle contractions varying continuously and interferences due to motion change the frequency content of the EMG-signal such that the results from FFT calculations are not as precise and reliable as in static measurement. FFT calculation made of dynamic motion may be specified by making use of motion sensors attached to a person during the test, by means of which sensors the interferences created in signals may be eliminated or limit the areas included in FFT calculation to advantageous in terms of calculation. In this case fatigue may be measured reliably e.g. during work or sports performance with a measuring/displaying device to be carried with a person.

An advantageous application of the invention measures development of motoric skills of a person. The method is utilized e.g. in rehabilitation after a person has been disabled, in training of professions requiring great accuracy or e.g. in sports training. EMG-signal is measured from one or several muscles during a performance. During the measurement a specific performance and its training part are aimed to be specified e.g. a golf swing or a tennis serve. The measuring sensors are placed on the skin overlying muscles participating in the performance at the middle of the muscle. The measuring is carried out through disposable sensors or through sensors integrated in clothing. The information of measuring is stored in a measuring device on the wrist, on the waist or in the pocket, which measures the EMG-signal with recognized methods. The measuring signal is calculated by means of various calculation algorithms, by calculating e.g. complexity values during the performance. The performance is tried to be separated into various phases and the result of the performance is fed also into the memory of the device. Complexity values from the entire performance are calculated and stored into the memory. As the motoric level develops the signal of complexity changes and the time-related synchronisation of muscles during a performance improves. The change is compared to the received performance results. Later on, the values may be utilized while restoring and further developing motoric skills. The results may be compared to the values of the database and in this way estimate the development of motoric learning and skill objectively.
In an advantageous application of the invention, the method is utilized for measuring the activeness level of a person which is necessary for follow-up of changes in activeness state of the central nervous system due to various reasons e.g. in connection with diseases such as dementia, Alzheimer disease, depression, chronic/acute fatigue and so on. Control of the state of fatigueness is useful also in some working positions requiring continuous concentrating such as surgery, flying/air control and so on.

In this application, the median value of a person is defined for complexity, which is compared to reference data. The person to be measured carries a measuring device, which measures at regular time intervals e.g. EMG-signal from the muscles of the arms, from which signal some of the parameters complexity, entropy or determinism is calculated. From the value, e.g. the mean value of a day or a week is calculated. The change with respect to the mean value on a long time period describes the change in activeness, variation in serotonin level, motoric learning and so on.

The device in accordance with the invention comprises sensors to be placed in the body or on the body surface for measuring signals produced by muscles, a device for analysis of the signals by nonlinear calculation methods and a feedback device for giving feedback. The device comprises advantageously sensors especially for measuring electrical signals produced by muscles. The sensors in themselves are conventional sensors for this purpose. The device for analysis of signals processes and analyzes signals and it has the necessary programmes for processing and analyzing signals with nonlinear calculation methods as earlier presented. In addition, the device comprises one or several recognized feedback devices, with which the user, the person examined or possibly some other person may receive information about the study and its results in real-time or later. Naturally, the information is also stored for later use.

The invention is not limited to the presented advantageous applications but it can vary within the frames of the idea of the invention formed in the claims.
CLAIMS

1. A method for identifying, measuring and analyzing abnormal neurological responses, characterized in that neurological diseases, pain, fatigue, power producing ability and/or activeness and/or symptoms connected with those are estimated by measuring signals produced by muscles and by analyzing signals with nonlinear calculation methods.

2. A method in accordance with claim 1, characterized in that electrical signals of muscles are measured with a measuring device.

3. A method in accordance with claim 1 or 2, characterized in that electrical signals of active muscles are measured with a measuring device.

4. A method in accordance with any of claims 1, 2 or 3, characterized in that results received by the method are compared to reference results stored in a database.

5. A method in accordance with any of claims 1-4, characterized in that the results received by the method are transmitted to a user by means of a feedback device.

6. A method in accordance with any of claims 1-4, characterized in that the received results are transmitted to the person examined by means of a personal feedback device.

7. A method in accordance with any of claims 1-6, characterized in that Parkinson's disease is diagnosed, the influence of rate of dosage of medicine is defined, monitored and controlled and the progression of the disease is followed by the method.

8. A method in accordance with any of claims 1-7, characterized in that pain is diagnosed, the influence of rate of dosage of medicine is defined, monitored and controlled and the influence of pain is followed by the method.

9. A method in accordance with any of claims 1-8, characterized in that the degree of fatigueness is measured by the method.

10. A method in accordance with any of claims 1-9, characterized in that power producing ability and changes in it are measured by the method.
11. A method in accordance with any of claims 1-10, characterized in that activeness of the central nervous system and changes in it are measured by the method.

12. A device for identifying, measuring and analyzing abnormal neurological responses, characterized in that the device comprises sensors to be placed in the body or on the body surface for measuring signals produced by muscles, a signal analyzing device for analyzing signals with nonlinear calculation algorithms and a feedback device for giving feedback.

13. A device in accordance with claim 12, characterized in that the device comprises sensors to be placed in the body or on the body surface for measuring electrical signals produced by muscles.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC8:** A61B 5/0488, G06F17/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

**IPC8:** A61B, G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

FI, SE, NO, DK (classes as above)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
<td>X</td>
<td>US 5361775 A (REMES et al.) 08 November 1994 (08.11.1994) the whole document Cited in the application</td>
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<tr>
<td>X</td>
<td>US 5092343 A (SPITZER ROBERT et al.) 03 March 1992 (03.03.1992) the whole document</td>
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<td>X</td>
<td>US 5662118 A (SKUBICK) 02 September 1997 (02.09.1997) the whole document</td>
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☐ Further documents are listed in the continuation of Box C. ✗ See patent family annex.

"A" Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "B" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means of document published prior to the international filing date but later than the priority date claimed

"T" Later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" Document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" Document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" Document of the same patent family

Date of the actual completion of the international search
08 September 2005 (08.09.2005)

Date of mailing of the international search report
23 September 2005 (23.09.2005)

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Form PCT/ISA/210 (second sheet) (April 2005)
INTernational Search Report

Observations where Certain Claims were found unsearchable (Continuation of Item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 1-11
   because they relate to subject matter not required to be searched by this Authority, namely:
   Claims 1-11 relate to a diagnostic method and method for treatment of the human or animal body by therapy (PCT Rule 39.1 (iv)).

2. ☐ Claims Nos.: 
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.: 
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Observations where Unity of Invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.: 

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: 

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2005)
<table>
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