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(54) MUSCLE TONE MEASURING APPARATUS

VORRICHTUNG ZUR MUSKELTONUSMESSUNG

APPAREIL DE MESURE DU TONUS MUSCULAIRE

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Description

Technical Field

[0001] The present invention relates to a muscle tonus measuring apparatus for measuring muscle tonus characteristics of Parkinson's disease patients and stroke patients, and objectively evaluating the muscle tonus characteristics.

Background Art

[0002] Abnormalities of muscle tonus caused by neuromuscular diseases are classified into spasticity and rigidity: the former is a pyramidal tract sign and the latter is an extrapyramidal sign. To detect the degree of those is quite important in neurological examination. However, it is difficult to evaluate the degree accurately unless a neurologist is experienced. Although the Modified Ashworth Scale for spasticity and the UPDRS (Unified Parkinson Disease Rating Scale) for muscle rigidity are known as evaluation indices that currently are used often in clinical trial, the criteria of both of them are semi-quantitative, and thus differences may arise between evaluators and with the same evaluator. Accordingly, the development of quantitative measuring devices for these is desired.

[0003] Patent Document 1 recites a muscle tonus measuring apparatus that causes the elbow joint of a subject to undergo passive flexion and extension movement, obtains an elastic coefficient for the elbow joint from the relationship between joint angle and joint torque, and measures the surface myoelectric potential of the biceps brachii muscle and the triceps brachii muscle at the same time. Patent Document 1 recites that a feature amount extracted from the elastic coefficient of the elbow joint and the surface myoelectric potentials is useful in identifying the severity of muscle rigidity in Parkinson's disease patients, and that a feature amount extracted from the surface myoelectric potential of the biceps brachii muscle is useful in distinguishing between a healthy subject and a Parkinson's disease patient.

[0004] An article titled "Measurement of Rigidity in Parkinson's Disease", published in Movement Disorders, vol. 12 No. 1, 1997, pp. 24-32, discloses a further muscle tonus measuring apparatus for causing an elbow joint of a subject to undergo passive flexion and extension movement. The elastic stiffness of the joint is calculated by assuming that the joint is moved in an approximately sinusoidal manner, and determining an estimate of an elastic stiffness across a number of flexion and extension phases.

[0005] Another article titled "Time-course analysis of stretch reflexes in hemiparetic subjects using an on-line spasticity measurement system", published in the Journal of Electromyography and Kinesiology 10 (2000) 1-14, discloses a spasticity measuring device in which a joint is moved using a mechanical system at a constant angular velocity from a first position through a predetermined stretching angle. Plots of the stretching angle are divided into five regions (I, II, III, IV, V). Regions I and V are the constant torque regions when the joint is not moving and regions II and IV are the regions when acceleration and deceleration occur. The data in the middle region III is compared to a base line over the same range that is calculated based on the difference between the torque levels at the I and V regions. This comparison is performed by fitting a third-order polynomial to the data in the III region and integrating the deviation between that fitted line and the base line over the III range.

Prior Art Documents

Patent Document

[0006] Patent Document 1: WO 2009/154117 pamphlet

Disclosure of Invention

Problem to be Solved by the Invention

[0007] With the muscle tonus measuring system recited in the aforementioned Patent Document 1, measuring the elastic coefficient of the elbow joint allows the identification of the severity of muscle rigidity in a Parkinson's disease patient, but it is not possible to distinguish between a healthy subject and a Parkinson's disease patient. Distinguishing between a healthy subject and a Parkinson's disease patient requires the separate measurement of surface myoelectric potential.

[0008] An object of the present invention is to provide a muscle tonus measuring apparatus with a simple configuration that can distinguish between a healthy subject and a Parkinson's disease patient without the measurement of surface myoelectric potential.

Means for Solving Problem

[0009] A muscle tonus measuring apparatus of the present invention includes a detection unit for causing a joint of a subject to undergo passive flexion and extension movement, and that is configured to detect a joint torque of the joint and a joint angle of the joint, and an arithmetic unit that is configured to perform arithmetic processing on an output signal from the detection unit, characterised in that the arithmetic unit is configured to divide a relationship between the joint torque and the joint angle in at least one of an extension phase and a flexion phase into two or more portions including a proximal-side portion and a distal-side portion according to a joint angle, and obtains an elastic coefficient of the joint from the relationship between the joint torque and the joint angle in the distal-side portion and the proximal-side portion.

Effects of the Invention

[0010] According to a muscle tonus measuring apparatus of the present invention, an objective indicator for distinguishing between a healthy subject and a Parkinson's disease patient without the measurement of surface myoelectric potential can be provided at low cost with a method similar to clinical examination techniques that conventionally have been performed by physicians in clinical examinations.

Brief Description of Drawings

[0011]

FIG. 1 is a diagram showing a schematic configuration of a muscle tonus measuring apparatus according to an embodiment of the present invention.

FIG. 2 is a diagram showing a data analysis technique in the muscle tonus measuring apparatus according to the embodiment of the present invention.

FIG. 3 is a representative raw waveform diagram of joint angles and joint torques for a healthy subject that are measured in Example 1.

FIG. 4 shows joint angle-torque variation curves in a dynamic flexion phase and a dynamic extension phase that were obtained from the raw waveform diagram shown in FIG. 3.

FIG. 5A is a diagram showing the relationship between UPDRS rigidity scores and full-range elastic coefficients in the flexion phase, which is obtained in Example 2.

FIG. 5B is a diagram showing the relationship between UPDRS rigidity scores and proximal elastic coefficients in the flexion phase, which is obtained in Example 2.

FIG. 5C is a diagram showing the relationship between UPDRS rigidity scores and distal elastic coefficients in the flexion phase, which is obtained in Example 2.

FIG. 6A is a diagram showing the relationship between UPDRS rigidity scores and full-range elastic coefficients in the extension phase, which is obtained in Example 2.

FIG. 6B is a diagram showing the relationship between UPDRS rigidity scores and proximal elastic coefficients in the extension phase, which is obtained in Example 2.

FIG. 6C is a diagram showing the relationship between UPDRS rigidity scores and distal elastic coefficients in the extension phase, which is obtained in Example 2.

FIG. 7 is a box plot showing distal elastic coefficients in the extension phase that are obtained in Example 2, sorted according to healthy subjects and Parkinson's disease patients.

Description of the Invention

[0012] In the above-described muscle tonus measuring apparatus of the present invention, it is preferable that the arithmetic unit divides the relationship between the joint torque and the joint angle in the extension phase into two or more portions including the proximal-side portion and the distal-side portion according to a joint angle, and obtains a distal elastic coefficient in the extension phase of the joint from the relationship between the joint torque and the joint angle in the distal-side portion. Accordingly, it is possible to distinguish between a healthy subject and a Parkinson's disease patient using only the distal elastic coefficient in the extension phase, thus enabling further simplified arithmetic processing.

[0013] In the above configuration, the arithmetic unit may further obtain the proximal elastic coefficient in the extension phase of the joint from the relationship between the joint torque and the joint angle in the proximal-side portion.

[0014] Alternatively, the arithmetic unit may divide the relationship between the joint torque and the joint angle in each of the extension phase and the flexion phase into two or more portions including the proximal-side portion and the distal-side portion according to a joint angle, and obtain a proximal elastic coefficient in the extension phase and a distal elastic coefficient in the extension phase of the joint from the relationship between the joint torque and the joint angle in the proximal-side portion and the distal-side portion in the extension phase; a proximal elastic coefficient in the flexion phase and a distal elastic coefficient in the flexion phase of the joint from the relationship between the joint torque and the joint angle in the proximal-side portion and the distal-side portion in the flexion phase; a full-range elastic coefficient in the extension phase of the joint in a range including the distal-side portion and the proximal-side=portion, from the relationship between the joint torque and the joint angle in the extension phase; and a full-range elastic coefficient in the flexion phase of the joint in a range including the distal-side portion and the proximal-side portion, from the relationship between the joint torque and the joint angle in the flexion phase. This enables distinguishing between a healthy subject and a Parkinson's disease patient even when using the proximal, distal, and full-range elastic coefficient in the extension phase, and the proximal, distal, and full-range elastic coefficient in the flexion phase.

[0015] It is preferable that the joint angle between the proximal-side portion and the distal-side portion is in a range of 59 degrees to 63 degrees inclusive.

[0016] It is preferable that the arithmetic unit divides the relationship between the joint torque and the joint angle into two portions according to a joint angle, the two portions being the proximal-side portion and the distal-side portion. It is possible to distinguish between a healthy subject and a Parkinson's disease patient with the simple technique of dividing the relationship between the joint torque and the joint angle into two portions according to a joint angle. In this case, the joint angle for dividing the relationship into the proximal-side portion and the distal-side portion is preferably in the range of 59 degrees to 63 degrees inclusive, or more preferably is 60 degrees.

[0017] The arithmetic unit may further obtain a sum of bias differences that is obtained by calculating differences between the joint torque in the flexion phase and the joint torque in the extension phase (bias difference) for a plurality of joint angles, and adding together the differences. This further enables identifying the severity of muscle rigidity (UPDRS 1 to 4) in a Parkinson's disease patient.

[0018] It is preferable that the joint is an elbow joint. This enables objectively distinguishing between a healthy subject and a Parkinson's disease patient with a method similar to clinical examination techniques that have been performed conventionally by physicians in clinical examinations.

[0019] Below, the present invention will be described in detail while disclosing a preferred embodiment. However, it goes without saying that the present invention is not limited to the following embodiment. For the sake of convenience in the description, the drawings that are referenced in the following description show simplifications of, among the constituent members of the embodiment of the present invention, only relevant members that are necessary for describing the present invention. The present invention therefore can include arbitrary constituent members that are not shown in the following drawings. Also, regarding the dimensions of the members in the drawings, the dimensions of the actual constituent members, the ratios of the dimensions of the members, and the like are not shown faithfully.

[0020] FIG. 1 shows the schematic configuration of a muscle tonus measuring apparatus for measuring muscle tonus characteristics through flexion and extension movements of an elbow joint of a patient, according to an embodiment of the present invention.

[0021] This muscle tonus measuring apparatus includes a detection unit 10 that detects the joint torque of the elbow joint where the elbow joint of a subject 1 undergoes passive flexion and extension movement and the joint angle of the elbow joint, and an arithmetic unit 50 that performs arithmetic processing on an output signal from the detection unit 10. As shown in FIG. 1, the detection unit 10 is fitted so as to sandwich the wrist joint portion of the subject 1, and an examiner 2 flexes and extends the elbow joint of the subject 1 via the detection unit 10.

[0022] The detection unit 10 includes a base 11 that has a substantially square-cornered U shape or is substantially U-shaped and can be considered to be a substantially rigid body.

[0023] A pair of force sensors 20a and 20b are fixed so as to oppose each other on a pair of sandwich plates 12a and 12b of the base 11 that oppose each other. The structure of the force sensors 20a and 20b is not limited as long as compressive force applied to the force sensors 20a and 20b can be detected, and general-purpose force sensors that are conventionally known can be used as the force sensors 20a and 20b, for example. If the direction in which the pair of force sensors 20a and 20b are in opposition is the Z axis, the force sensors 20a and 20b detect at least force in the Z axis direction. For example, general-purpose small triaxial force sensors that detect forces in three axial directions including the Z axis can be used as the force sensors 20a and 20b. By detecting forces in the orthogonal biaxial directions that are orthogonal to the Z axis direction in addition to force in the Z axis direction, the direction of the force applied to the subject 1 by the examiner 2 can be revised, and data on the detected force in the Z axis direction can be corrected. In order to alleviate discomfort due to the force sensors 20a and 20b being in direct contact with the skin of the subject 1 when causing flexion and extension movements of the elbow joint, soft pads may be attached to the mutually opposing faces of the force sensors 20a and 20b (the faces brought into contact with the wrist joint portion of the subject 1).

[0024] A gyroscope 30 is fixed on a bridge plate 13 that connects the pair of sandwich plates 12a and 12b of the base 11. The gyroscope 30 detects changes in the orientation of the detection unit 10 in which the gyroscope 30 is included, which changes following flexion and extension movements of the elbow joint of the subject 1.

[0025] When the elbow joint of the subject 1 is caused to undergo flexion and extension movement, the detection unit 10 moves along a circular arc with the elbow joint serving as the center. During flexion and extension movements of the elbow joint, the orientation of the detection unit 10 is maintained such that the Z axis is always parallel to the tangential direction of this circular arc. The force sensors 20a and 20b output a voltage according to the force in the Z axis direction applied by the examiner 2 to the subject 1 when the examiner 2 causes the elbow joint of the subject 1 to undergo flexion and extension movements. The voltage output from the force sensors 20a and 20b is amplified by a force sensor amplifier 21 as necessary, and thereafter is input to the arithmetic unit 50 via an A/D conversion board 51. The voltage output from the gyroscope 30 according to change in the orientation thereof is input to the arithmetic unit 50 via the A/D conversion board 51.

[0026] For example, a general-purpose personal computer can be used as the arithmetic unit 50. An output apparatus 52 may be connected to the arithmetic unit 50. For example, any of various displays and printers can be used as the output apparatus 52.

[0027] FIG. 2 is a diagram showing a technique of data analysis performed by the arithmetic unit 50 in the muscle tonus measuring apparatus according to the present embodiment.

[0028] Ajoint torque and a joint angle of the elbow joint of the subject 1 are measured while repeating four phases, namely (1) a maximal extension static phase, (2) a dynamic flexion phase, (3) a maximal flexion static phase, and (4) a dynamic extension phase.

[0029] The joint torque is calculated based on the force in the Z axis direction detected via the force sensors 20a and 20b, and the distance between the elbow joint of the subject 1 and the position where the detection unit 10 is fitted (i.e., the radius of the circular arc along which the detection unit 10 moves in the flexion and extension movements), which has been measured separately. The joint angle is calculated by integrating the change in the orientation (angular velocity) of the detection unit 10 detected via the gyroscope 30.

[0030] Change over time (a waveform) in the relationship between the joint torque and the joint angle in the dynamic extension phase in particular is extracted from change over time (raw waveforms) in the joint torque and the joint angle when the four phases are repeated. Furthermore, the relationship between the joint torque and the joint angle in the dynamic extension phase is divided into two portions, namely a proximal-side (flexion-side) portion and a distal-side (extension-side) portion, according to a joint angle, and the elastic coefficient of the elbow joint (distal elastic coefficient in the extension phase) is calculated from the relationship between the joint torque and the joint angle in the distal-side dynamic extension phase. The elastic coefficient can be obtained from the slope of the regression line of the graph (waveform) indicating the relationship between the joint torque and the joint angle.

[0031] Data regarding the distal elastic coefficient in the extension phase obtained by the arithmetic unit 50 may be stored in the arithmetic unit 50. Also, the arithmetic unit 50 may analyze the stored data with a statistical technique, for example. A raw waveform diagram indicating change over time in the joint angle and the joint torque, the results of the calculation of the distal elastic coefficient in the extension phase, the results of a comparison between a measured distal elastic coefficient in the extension phase and stored data, the results of an UPDRS evaluation, and the like are output to the output apparatus 52 in accordance with a request from the examiner.

[0032] With the muscle tonus measuring apparatus recited in Patent Document 1 described above, a full-range elastic coefficient in the dynamic extension phase and a full-range elastic coefficient in the dynamic flexion phase are calculated from the relationship between the joint torque and the joint angle in the dynamic extension phase and the dynamic flexion phase in the joint angle range of 10 degrees to 110 degrees. In other words, this is based on the idea that there is one elastic coefficient for each of the dynamic extension phase and the dynamic flexion phase in this joint angle range. Although such elastic coefficients demonstrate a good correlation with the UPDRS rigidity score, which is a scale for the clinical assessment of Parkinson's disease, it has not been possible to distinguish between a healthy subject (UPDRS 0) and a Parkinson's disease patient who has a slight amount of muscle rigidity (UPDRS 1).

[0033] In view of this, as a result of detailed examination of change over time in the relationship between the joint torque and the joint angle in the dynamic extension phase and the dynamic flexion phase, the inventors of the present invention found that a healthy subject in particular does not have one elastic coefficient in the dynamic extension phase and the dynamic flexion phase, but rather has different elastic coefficients in the proximal side and the distal side, the boundary between which is in the vicinity of the joint angle of 60 degrees. Then, as a result of examination of the relationship between UPDRS rigidity scores and proximal-side and distal-side elastic coefficients in the dynamic extension phase and the dynamic flexion phase, it was found that it is possible to distinguish between a healthy subject and a Parkinson's disease patient by using the distal-side elastic coefficient in the dynamic extension phase (distal elastic coefficient in the extension phase), and the present invention was achieved. The technique of performing analysis on characteristics of joint movement that have been divided into a proximal-side portion and a distal-side portion according to a joint angle is unprecedented.

[0034] The inventors of the present invention also found that it is possible to distinguish between a healthy subject and a Parkinson's disease patient even when using a total of six elastic coefficients, namely the proximal-side, distal-side, and full-range elastic coefficients in the dynamic extension phase, and the proximal-side, distal-side, and full-range elastic coefficients in the dynamic flexion phase. Here, "full-range" refers to the joint angle range in the dynamic extension phase and the dynamic flexion phase before the division into a proximal side portion and a distal side portion.

[0035] According to the present invention, distinguishing between a healthy subject and a Parkinson’s disease patient does not require the measurement of surface myoelectric potential, which is necessary in Patent Document 1. If the distal elastic coefficient in the extension phase (or the aforementioned six elastic coefficients) obtained with the present invention is used with at least one of the bias difference and the elastic coefficients in the dynamic extension phase and the dynamic flexion phase (full-range elastic coefficient in the extension phase and the full-range elastic coefficient in the flexion phase) recited in Patent Document 1, it is possible to provide an objective evaluation of all scores from UPDRS 0 to 4 with an apparatus that has the simple configuration shown in FIG. 1 that omits the use of a surface myoelectric potentiometer.

[0036] The joint angle for division into a proximal side portion and a distal side portion is not particularly limited, but is preferably in the range of 59 degrees to 63 degrees inclusive, or more preferably is 60 degrees. This enables more accurate distinguishing between a healthy subject and a Parkinson’s disease patient.

[0037] The present invention is not limited to the above embodiment or the following examples, and various modifications can be made.

[0038] For example, the shape of the base where the force sensors 20a and 20b and the gyroscope 30 are mounted does not need to be a substantially square-cornered U shape or substantially U-shaped as in the above embodiment, and for example, the overall shape thereof may be any of a circle, an ellipse and various polygons including a quadrangle, for instance, or may be a toroidal shape with a through-hole in the center. Furthermore, for the purpose of improving the fit to a subject, the base may have a movable portion, or part of the base or the entire base may have flexibility.

[0039] Instead of the pair of force sensors 20a and 20b, a single force sensor for detecting pushing and pulling forces applied when the examiner 2 causes the elbow joint of the subject 1 to undergo flexion and extension movement may be used.

[0040] A stage for supporting the subject’s joint may be provided, and a distance sensor for automatically measuring the distance between this stage and the detection unit 10 may further be provided. Accordingly, the turning radius of the detection unit 10 necessary for calculating a joint torque can be measured easily.

[0041] In the above embodiment, the gyroscope 30 for measuring a joint angle is mounted on the base 11 together with the force sensors 20a and 20b. Accordingly, the entire apparatus can be reduced in size, and a joint torque and a joint angle can be simultaneously measured by merely fitting the detection unit 10 around the subject. However, in the present invention, the method for measuring a joint angle is not limited to this, and a known angular change measurement method can be utilized. For example, separately from the detection unit 10 including the force sensors 20a and 20b, a sensor for angle measurements (for example, a potentiometer or a rotary encoder) may be fitted in the vicinity of a joint of the subject via a jig.

[0042] The arithmetic unit for performing predetermined arithmetic processing using measured data and the display apparatus for displaying an arithmetic result may be reduced in size and mounted on the detection unit 10.

[0043] It is of course possible to apply the measuring apparatus of the present invention to joints other than the elbow joint (e.g., a wrist or a knee joint). The shape of the detection unit 10 can be changed appropriately depending on the joint to which it is applied.

[0044] The apparatus of the present invention may be used to further obtain the proximal-side elastic coefficient in the dynamic extension phase (proximal elastic coefficient in the extension phase) in addition to the distal elastic coefficient in the extension phase. For example, if the distal elastic coefficient in the extension phase and the proximal elastic coefficient in the extension phase are compared, it is possible to evaluate whether the elastic coefficient in the extension phase is made up of two different elastic coefficients on the distal side and the proximal side, or made up of one elastic coefficient that has no difference between the two sides. It is possible for the result of this evaluation to be used as supplementary data when objectively distinguishing between a healthy subject and a Parkinson’s disease patient using the distal elastic coefficient in the extension phase.

[0045] Furthermore, the apparatus of the present invention may be used to calculate a feature amount such as the full-range elastic coefficient in the dynamic flexion phase, the full-range elastic coefficient in the dynamic extension phase, and the sum of bias differences, which are recited in Patent Document 1. This enables objectively identifying the severity of muscle rigidity in a Parkinson’s disease patient.

[0046] Here, "sum of bias differences" is obtained as described below. In the joint angle-torque variation curve obtained by causing the joint to undergo flexion and extension movement (e.g., see later-described FIG. 4), the "bias difference" for a certain joint angle is the result of obtaining the difference between the average value of torque in all measurements in the dynamic flexion phase (dynamic flexion phase bias) and the average value of torque in all measurements in the dynamic extension phase (dynamic extension phase bias). The bias difference is calculated for multiple joint angles, and the calculated bias differences are added together to obtain the "sum of bias differences". It is preferable that the joint angles at which the bias difference is obtained include a distal-side angle (e.g., 30°), a proximal-side angle (e.g., 90°), and the angle between the distal side and the proximal side (e.g., 60°).

[0047] Also, a torque differential value may be calculated by performing temporal differentiation on joint torque in the dynamic flexion phase and/or the dynamic extension phase as recited in Patent Document 1. This torque differential value can be used as supplementary data when objectively distinguishing between a healthy subject and a Parkinson's disease patient using the distal elastic coefficient in the extension phase (or the six elastic coefficients described above). This also enables objectively distinguishing between the presence and absence of tremors in a Parkinson's disease patient.

[0048] In the above description, the relationship between the joint torque and the joint angle in the dynamic extension phase and the dynamic flexion phase is divided into two portions, namely the proximal-side portion and the distal-side portion, according to the joint angle, but the present invention is not limited to this, and the relationship may be divided into three or more portions including the proximal-side portion and the distal-side portion. For example, a configuration is possible in which the joint angle range of the proximal-side portion and the joint angle range of the distal-side portion are separated from each other instead of being continuous with each other.

[0049] Although the example of distinguishing between a healthy subject and a Parkinson's disease patient using the distal elastic coefficient in the extension phase is described above, the present invention is not limited to this. Specifically, depending on the joint that is caused to undergo flexion and extension movement, it is possible to be able distinguish between a healthy subject and a Parkinson's disease patient using any one among the proximal elastic coefficient in the flexion phase, the distal elastic coefficient in the flexion phase, the proximal elastic coefficient in the extension phase, and the distal elastic coefficient in the extension phase.

[0050] In Examples 1 and 2 described below, the flexion phase and the extension phase are obtained after extracting a portion corresponding to the joint angle range of 10 to 110 degrees from a raw waveform diagram of the joint torque and the joint angle obtained when causing a joint to undergo flexion and extension movement, but the joint angle range of the flexion phase and the extension phase is not limited to 10 degrees to 110 degrees. The lower limit value and the upper limit value of the joint angle range of the flexion phase and the extension phase may be greater or less than the above values. This joint angle range may be changed appropriately according to the subject and the joint that is caused to undergo flexion and extension movement. Furthermore, the angle ranges of the distal-side portion and the proximal-side portion also can be changed appropriately.

Example 1

<Object>

[0051] As described above, with a healthy subject, the elastic coefficients in the passive dynamic extension phase and dynamic flexion phase take different values on the proximal side and the distal side. In view of this, the optimum joint angle was obtained for dividing the elastic coefficients in the dynamic extension phase and the dynamic flexion phase for a healthy subject into a proximal-side portion and a distal-side portion.

<Measurement>

[0052] The muscle tonus measuring apparatus shown in FIG. 1 was used to measure the joint angle and the joint torque for both elbow joints of 20 healthy subjects (15 men and 5 women, aged 55 to 85).

[0053] The subjects were instructed to remain relaxed resting in a sitting position, and the examiner caused the elbow joint of each subject to undergo passive flexion and extension movement while supporting the subject's elbow joint portion with one hand and holding the subject's wrist joint portion with the other hand via the detection unit 10. In the measurement, the elbow joint started at the maximal extension position and was held still for three seconds or more, then flexed to the maximal flexion position over two seconds and held still there for three or more seconds, and then extended to the maximal extension position over two seconds and held still there for three or more seconds, and this flexion and extension movement was repeated for 60 seconds. One session included four to five instances of this flexion and extension movement. This measurement was performed on each subject one or two times for both the left and right upper limbs, and thus data for 520 instances (260 instances of flexion and 260 instances of extension) was obtained with all of the subjects.

[0054] FIG. 3 shows a raw waveform diagram of representative results of measuring the joint angle and the joint torque.

<Analysis>

[0055] The following analysis was performed on each data piece among the data (raw waveform diagram) for the 520 instances obtained in the aforementioned measurement.

[0056] First, a portion corresponding to the joint angle range of 10 to 110 degrees was extracted from the raw waveform diagram of FIG. 3 that was obtained in the aforementioned measurement, and joint angle-torque variation curves in the flexion phase and the extension phase such as those shown in FIG. 4 were obtained.

[0057] For both the flexion phase and the extension phase, the optimal angle (dividing angle) for dividing the joint angle-torque variation curves was obtained, and that optimal angle was used to obtain a regression line for the joint angle-torque variation curves in the proximal-side portion and the distal-side portion. This calculation was performed using a likelihood-maximizing method.

[0058] In the case where the p value of the likelihood ratio test satisfies $p<0.05$, approximating the joint angle-torque variation curve in the joint angle range of 10 to 110 degrees by two regression lines was determined to be more preferable than approximating it by one regression line, and the curve was considered to be "significant example".

[0059] A 95% confidence interval was then obtained for the dividing angle of the "significant example".

<Results>

[0060] The results are shown organized in Table 1.

[Table 1]

Significant examples in all sessions	Significant examples in flexion phase	Flexion phase dividing angle (95% confidence interval)	Significant examples in extension phase	Extension phase dividing angle (95% confidence interval)
520/520 (100%)	260/260 (100%)	58.1° (55.3° -60.9°)	260/260 (100%)	61.1° (59.2° -62.9°)

[0061] As shown in Table 1, the results obtained for all of the pieces of data on the 520 instances for healthy subjects indicated that it is preferable that the joint angle-torque variation curves are approximated by two regression lines in both the flexion phase and the extension phase. The dividing angles in this case were 58.1 degrees for the flexion phase and 61.1 degrees for the extension phase. In both the flexion phase and the extension phase, the angle of 60 degrees was included in the 95% confidence interval for the dividing angle. Accordingly, there is no problem with setting the dividing angle to 60 degrees for both the flexion phase and the extension phase.

Example 2

<Object>

[0062] The extent of correlation with UPDRS rigidity scores was investigated for proximal-side and distal-side elastic coefficients obtained when dividing joint angle-torque variation curves in the dynamic extension phase and the dynamic flexion phase into two portions using the dividing angle of 60 degrees that was obtained in Example 1.

<Measurement>

[0063] With respect to 24 patients diagnosed as having Parkinson's disease based on Parkinson's disease diagnostic criteria (1995) by the research study group of specified diseases and neurodegenerative diseases of the Ministry of Health and Welfare (17 men and 7 women, aged 47 to 85), and the above-described 20 healthy subjects in Example 1 (15 men and 5 women, aged 55 to 85), the joint angle and the joint torque were measured using the muscle tonus measuring apparatus shown in FIG. 1.

[0064] Prior to the measurement, the healthy subjects underwent neurological examination, and the Parkinson's disease patients were assessed using UPDRS (Unified Parkinson Disease Rating Scale) Part III, and muscle rigidity was given a score in 5 levels from 0 to 4 (see Table 2).

[Table 2]

Muscle rigidity scores (Patient at rest. Determine based on main joints. Cogwheel phenomenon not recorded.)
0: Absent.
1: Slight or inducible by mirror movement or other movements.
2: Mild to moderate muscle rigidity.
3: Marked muscle rigidity, but range of joint motion is normal.

(continued)

Muscle rigidity scores (Patient at rest. Determine based on main joints. Cogwheel phenomenon not recorded.)
4: Severe muscle rigidity, and range of joint motion is limited.

[0065] The joint angle and the joint torque were measured using the same method as in Example 1 for the left and right upper limbs of the healthy subjects and the Parkinson's disease patients. At the same time, the surface myoelectric potential was measured with surface electrodes affixed at positions on the biceps brachii muscle and the triceps brachii muscle of the subjects. The data on healthy subjects clinically determined to have muscle rigidity and data considered to include obvious voluntary movement based on visual observation of an electromyogram were excluded from the 40 data pieces on the healthy subjects and the 48 data pieces on the Parkinson's disease patients, thus ultimately obtaining a total of 74 data pieces, namely 31 data pieces on healthy subjects and 43 data pieces on Parkinson's disease patients.

<Analysis>

[0066] The following analysis was performed on each of the aforementioned 74 data pieces.

[0067] First, the portion corresponding to the joint angle range of 10 to 110 degrees was extracted from the raw waveform diagram indicating joint angles and joint torques, and joint angle-torque variation curves in the flexion phase and the extension phase were obtained.

[0068] Then, a "full-range elastic coefficient in the flexion phase" was obtained from the slope of the regression line of the joint angle-torque variation curve in the flexion phase. Similarly, a "full-range elastic coefficient in the extension phase" was obtained from the slope of the regression line of the joint angle-torque variation curve in the extension phase.

[0069] Next, the joint angle-torque variation curve in the flexion phase was divided into two portions using the joint angle of 60 degrees, a "distal elastic coefficient in the flexion phase" was obtained from the slope of the regression line for the 10-degree to 60-degree portion, and a "proximal elastic coefficient in the flexion phase" was obtained from the slope of the regression line for the 60-degree to 110-degree portion. Similarly, the joint angle-torque variation curve in the extension phase was divided into two portions using the joint angle of 60 degrees, a "distal elastic coefficient in the extension phase" was obtained from the slope of the regression line for the 10-degree to 60-degree portion, and a "proximal elastic coefficient in the extension phase" was obtained from the slope of the regression line for the 60-degree to 110-degree portion.

[0070] Then, the correlation that the three types of elastic coefficients described above have with UPDRS rigidity scores was obtained for both the flexion phase and the extension phase.

[0071] Lastly, a test was performed between two groups, namely healthy subjects (UPDRS 0) and slight muscle rigidity (UPDRS 1).

<Results>

[0072] FIGS. 5A, 5B, and 5C show the relationships that the full-range, proximal, and distal elastic coefficients in the flexion phase have with UPDRS rigidity scores. In these figures, "r" denotes the coefficient of correlation with UPDRS rigidity scores. The full-range elastic coefficient and the distal elastic coefficient demonstrated approximately the same extent of good correlation with UPDRS rigidity scores. Also, no significant difference between UPDRS 0 and UPDRS 1 was observed in either case.

[0073] FIGS. 6A, 6B, and 6C show the relationships that the full-range, proximal, and distal elastic coefficients in the extension phase have with UPDRS rigidity scores. In these figures, "r" denotes the coefficient of correlation with UPDRS rigidity scores. The distal elastic coefficient demonstrated the best correlation with UPDRS rigidity scores. Moreover, a significant difference between UPDRS 0 and UPDRS 1 was observed with the distal elastic coefficient ($p=0.0018$).

[0074] FIG. 7 is a box plot showing distal elastic coefficients in the extension phase sorted according to healthy subjects and Parkinson's disease patients (PD patients). Letting the cutoff value for the distal elastic coefficient in the extension phase be 0.50, a sensitivity of 91% and a specificity of 65% were observed, and the distal elastic coefficient in the extension phase was considered to be useful in distinguishing between a healthy subject and a Parkinson's disease patient.

[0075] Logistic discrimination was carried out taking into consideration the six elastic coefficients (the full-range elastic coefficient in the flexion phase, the distal elastic coefficient in the flexion phase, the proximal elastic coefficient in the flexion phase, the full-range elastic coefficient in the extension phase, the distal elastic coefficient in the extension phase, and the proximal elastic coefficient in the extension phase) and factors such as age, gender, and left/right side, and the obtained results indicated a sensitivity of 90.9%, a specificity of 81.3%, and a correct discrimination rate of 85.2% in the discrimination between a healthy subject and a Parkinson's disease patient. In other words, this suggested that a useful screening test can be performed when the full-range, proximal, and distal elastic coefficients in the flexion phase, and the full-range, proximal, and distal elastic coefficients in the extension phase are all used.

[0076] The embodiment and examples described above are all merely intended to clarify the technical content of the present invention, and the present invention is defined by the attached claims.

Industrial Applicability

[0077] Although the utilization field of the present invention is not particularly limited, the present invention can be utilized over a wide range, such as the determination of the severity of Parkinson's disease, and the determination of therapeutic effects before and after antiparkinson drug administration.

Description of Reference Numerals

[0078]

10	Detection unit
11	Base
12a,12b	Sandwich plate
13	Bridge plate
20a,20b	Force sensor
21	Force sensor amplifier
30	Gyroscope
50	Arithmetic unit
51	A/D conversion board
52	Output apparatus

Claims

1. A muscle tonus measuring apparatus comprising:

a detection unit (10) configured to detect a joint torque of the joint of a subject and a joint angle of the same joint, where the joint is undergoing passive flexion and extension movement; and
an arithmetic unit (50) that is configured to perform arithmetic processing on an output signal from the detection unit,

characterised in that the arithmetic unit is configured to divide a relationship between the joint torque and the joint angle in at least one of an extension phase and a flexion phase into two or more portions including a proximal-side portion and a distal-side portion according to a joint angle, and to obtain an elastic coefficient of the joint from the relationship between the joint torque and the joint angle in the distal-side portion and the proximal-side portion.

2. The muscle tonus measuring apparatus according to claim 1, wherein the arithmetic unit is configured to divide the relationship between the joint torque and the joint angle in the extension phase into two or more portions including the proximal-side portion and the distal-side portion according to a joint angle, and obtain a distal elastic coefficient in the extension phase of the joint from the relationship between the joint torque and the joint angle in the distal-side portion.

3. The muscle tonus measuring apparatus according to claim 1,
wherein the arithmetic unit is configured to divide the relationship between the joint torque and the joint angle in each of the extension phase and the flexion phase into two or more portions including the proximal-side portion and the distal-side portion according to a joint angle, and obtain:

a proximal elastic coefficient in the extension phase and a distal elastic coefficient in the extension phase of the joint from the relationship between the joint torque and the joint angle in the proximal-side portion and the distal-side portion in the extension phase,
a proximal elastic coefficient in the flexion phase and a distal elastic coefficient in the flexion phase of the joint from the relationship between the joint torque and the joint angle in the proximal-side portion and the distal-side

portion in the flexion phase,
a full-range elastic coefficient in the extension phase of the joint in a range including the distal-side portion and the proximal-side portion, from the relationship between the joint torque and the joint angle in the extension phase, and
a full-range elastic coefficient in the flexion phase of the joint in a range including the distal-side portion and the proximal-side portion, from the relationship between the joint torque and the joint angle in the flexion phase.

4. The muscle tonus measuring apparatus according to any of claims 1 to 3,
wherein the joint angle between the proximal-side portion and the distal-side portion is in a range of 59 degrees to 63 degrees inclusive.

5. The muscle tonus measuring apparatus according to any of claims 1 to 4,
wherein the arithmetic unit is configured to divide the relationship between the joint torque and the joint angle into two portions according to a joint angle, the two portions being the proximal-side portion and the distal-side portion.

6. The muscle tonus measuring apparatus according to any of claims 1 to 5,
wherein the arithmetic unit is further configured to obtain a sum of bias differences that is obtained by calculating differences between the joint torque in the flexion phase and the joint torque in the extension phase for a plurality of joint angles, and adding together the differences.

7. The muscle tonus measuring apparatus according to any of claims 1 to 6,
wherein the joint is an elbow joint.

Patentansprüche

1. Ein Muskeltonusmessgerät, aufweisend:

eine Detektiereinheit (10), die eingerichtet ist, um eine Gelenktorsion des Gelenks eines Gelenks eines Subjekts und einen Gelenkwinkel desselben Gelenks zu detektieren, wobei das Gelenk eine passive Flexions- und Extensionsbewegung erfährt;
eine arithmetische Einheit (50), die eingerichtet ist, um auf ein Ausgangssignal von der Detektiereinheit hin arithmetische Verarbeitungen durchzuführen;
dadurch gekennzeichnet, dass die arithmetische Einheit eingerichtet ist, um eine Beziehung zwischen der Gelenktorsion und dem Gelenkwinkel in mindestens einer von einer Extensionsphase und einer Flexionsphase gemäß eines Gelenkwinkels in zwei oder mehrere Abschnitte, umfassend einen Abschnitt proximaler Seite und einen Abschnitt distaler Seite, zu unterteilen, und
um einen Elastizitätskoeffizienten des Gelenks aus der Beziehung zwischen der Gelenktorsion und dem Gelenkwinkel in dem Abschnitt distaler Seite und dem Abschnitt proximaler Seite zu erhalten.

2. Das Muskeltonusmessgerät gemäß Anspruch 1, wobei die arithmetische Einheit eingerichtet ist, um die Beziehung zwischen der Gelenktorsion und dem Gelenkwinkel in der Extensionsphase gemäß eines Gelenkwinkels in zwei oder mehrere Abschnitte, umfassend den Abschnitt proximaler Seite und den Abschnitt distaler Seite, zu unterteilen, und einen distalen Elastizitätskoeffizienten in der Extensionsphase des Gelenks aus der Beziehung zwischen der Gelenktorsion und dem Gelenkwinkel in dem Abschnitt distaler Seite zu erhalten.

3. Das Muskeltonusmessgerät gemäß Anspruch 1, wobei die arithmetische Einheit eingerichtet ist, um die Beziehung zwischen der Gelenktorsion und dem Gelenkwinkel in sowohl der Extensionsphase als auch in der Flexionsphase gemäß eines Gelenkwinkels in zwei oder mehrere Abschnitte, umfassend den Abschnitt proximaler Seite und den Abschnitt distaler Seite, zu unterteilen und um Folgendes zu erhalten:

einen proximalen Elastizitätskoeffizienten in der Extensionsphase und einen distalen Elastizitätskoeffizienten in der Extensionsphase des Gelenks aus der Beziehung zwischen der Gelenktorsion und dem Gelenkwinkel in dem Abschnitt proximaler Seite und dem Abschnitt distaler Seite in der Extensionsphase,
einen proximalen Elastizitätskoeffizienten in der Flexionsphase und einen distalen Elastizitätskoeffizienten in der Flexionsphase des Gelenks aus der Beziehung zwischen der Gelenktorsion und dem Gelenkwinkel in dem Abschnitt proximaler Seite und in dem Abschnitt distaler Seite in der Flexionsphase,
einen Gesamtbereichselastizitätskoeffizienten in der Extensionsphase des Gelenks in einem Bereich, umfas-

send den Abschnitt distaler Seite und den Abschnitt proximaler Seite, aus der Beziehung zwischen der Gelenktorsion und dem Gelenkwinkel in der Extensionsphase, und
einen Gesamtbereichselastizitätskoeffizienten in der Flexionsphase des Gelenks in einem Bereich, umfassend den Abschnitt distaler Seite und den Abschnitt proximaler Seite, aus der Beziehung zwischen der Gelenktorsion und dem Gelenkwinkel in der Flexionsphase.

4. Das Muskeltonusmessgerät gemäß einem der Ansprüche 1 bis 3, wobei der Gelenkwinkel zwischen dem Abschnitt proximaler Seite und dem Abschnitt distaler Seite in einem Bereich von ab 59 Grad bis inklusive 63 Grad liegt.

5. Das Muskeltonusmessgerät gemäß einem der Ansprüche 1 bis 4, wobei die arithmetische Einheit eingerichtet ist, um die Beziehung zwischen der Gelenktorsion und dem Gelenkwinkel gemäß eines Gelenkwinkels in zwei Abschnitte zu unterteilen, wobei die zwei Abschnitte der Abschnitt proximaler Seite und der Abschnitt distaler Seite sind.

6. Das Muskeltonusmessgerät gemäß einem der Ansprüche 1 bis 5, wobei die arithmetische Einheit ferner eingerichtet ist, um eine Summe von Vorspannungsdifferenzen zu erhalten, die durch Berechnen der Differenzen zwischen der Gelenktorsion in der Flexionsphase und der Gelenktorsion in der Extensionsphase für eine Mehrzahl von Gelenkwinkeln und Zusammenzählen der Differenzen erhalten wird.

7. Das Muskeltonusmessgerät gemäß einem der Ansprüche 1 bis 6, wobei das Gelenk ein Ellenbogengelenk ist.

Revendications

1. Appareil de mesure du tonus musculaire comprenant :

une unité de détection (10) configurée pour détecter un couple articulaire de l’articulation d’un sujet et un angle articulaire de la même articulation, lorsque l’articulation subit une flexion passive et un mouvement d’extension ;
une unité arithmétique (50) qui est configurée pour effectuer un traitement arithmétique sur le signal émis par l’unité de détection ;
caractérisé en ce que l’unité arithmétique est configurée pour diviser une relation entre le couple articulaire et l’angle articulaire pendant au moins une parmi une phase d’extension et une phase de flexion en deux parties ou plus comprenant une partie côté proximal et une partie côté distal selon un angle articulaire et
pour obtenir un coefficient d’élasticité de l’articulation à partir de la relation entre le couple articulaire et l’angle articulaire dans la partie côté distal et la partie côté proximal.

2. Appareil de mesure du tonus musculaire selon la revendication 1, dans lequel l’unité arithmétique est configurée pour diviser la relation entre le couple articulaire et l’angle articulaire pendant la phase d’extension en deux parties ou plus, comprenant la partie côté proximal et la partie côté distal selon un angle articulaire, et pour obtenir un coefficient d’élasticité distal pendant la phase d’extension de l’articulation à partir de la relation entre le couple articulaire et l’angle articulaire dans la partie côté distal.

3. Appareil de mesure du tonus musculaire selon la revendication 1,
dans lequel l’unité arithmétique est configurée pour diviser la relation entre le couple articulaire et l’angle articulaire pendant chacune de la phase d’extension et de la phase de flexion en deux parties ou plus, comprenant la partie côté proximal et la partie côté distal en fonction d’un angle articulaire, et pour obtenir :

un coefficient d’élasticité proximal pendant la phase d’extension et un coefficient d’élasticité distal dans la phase d’extension de l’articulation à partir de la relation entre le couple articulaire et l’angle articulaire dans la partie côté proximal et dans la partie côté distal pendant la phase d’extension,
un coefficient d’élasticité proximal pendant la phase de flexion et un coefficient d’élasticité distal pendant la phase de flexion de l’articulation à partir de la relation entre le couple articulaire et l’angle articulaire dans la partie côté proximal et la partie côté distal pendant la phase de flexion,
un coefficient d’élasticité sur toute l’amplitude pendant la phase d’extension de l’articulation dans une plage comprenant la partie côté distal et la partie côté proximal, à partir de la relation entre le couple articulaire et l’angle articulaire pendant la phase d’extension, et
un coefficient d’élasticité sur toute l’amplitude pendant la phase de flexion de l’articulation dans une plage comprenant la partie côté distal et la partie côté proximal, à partir de la relation entre le couple articulaire et l’angle articulaire pendant la phase de flexion.

4. Appareil de mesure du tonus musculaire selon l'une quelconque des revendications 1 à 3, dans lequel l'angle articulaire entre la partie côté proximal et la partie côté distal se situe dans une plage de 59 degrés à 63 degrés inclus.

5. Appareil de mesure du tonus musculaire selon l'une quelconque des revendications 1 à 4, dans lequel l'unité arithmétique est configurée pour diviser la relation entre le couple articulaire et l'angle articulaire en deux parties selon un angle articulaire, les deux parties étant la partie côté proximal et la partie côté distal.

6. Appareil de mesure du tonus musculaire selon l'une quelconque des revendications 1 à 5, dans lequel l'unité arithmétique est en outre configurée pour obtenir une somme des différences de déformation obtenues en calculant des différences entre le couple articulaire pendant la phase de flexion et le couple articulaire pendant la phase d'extension pour une pluralité d'angles articulaires, et en additionnant les différences.

7. Appareil de mesure du tonus musculaire selon l'une quelconque des revendications 1 à 6, dans lequel l'articulation est une articulation de coude.

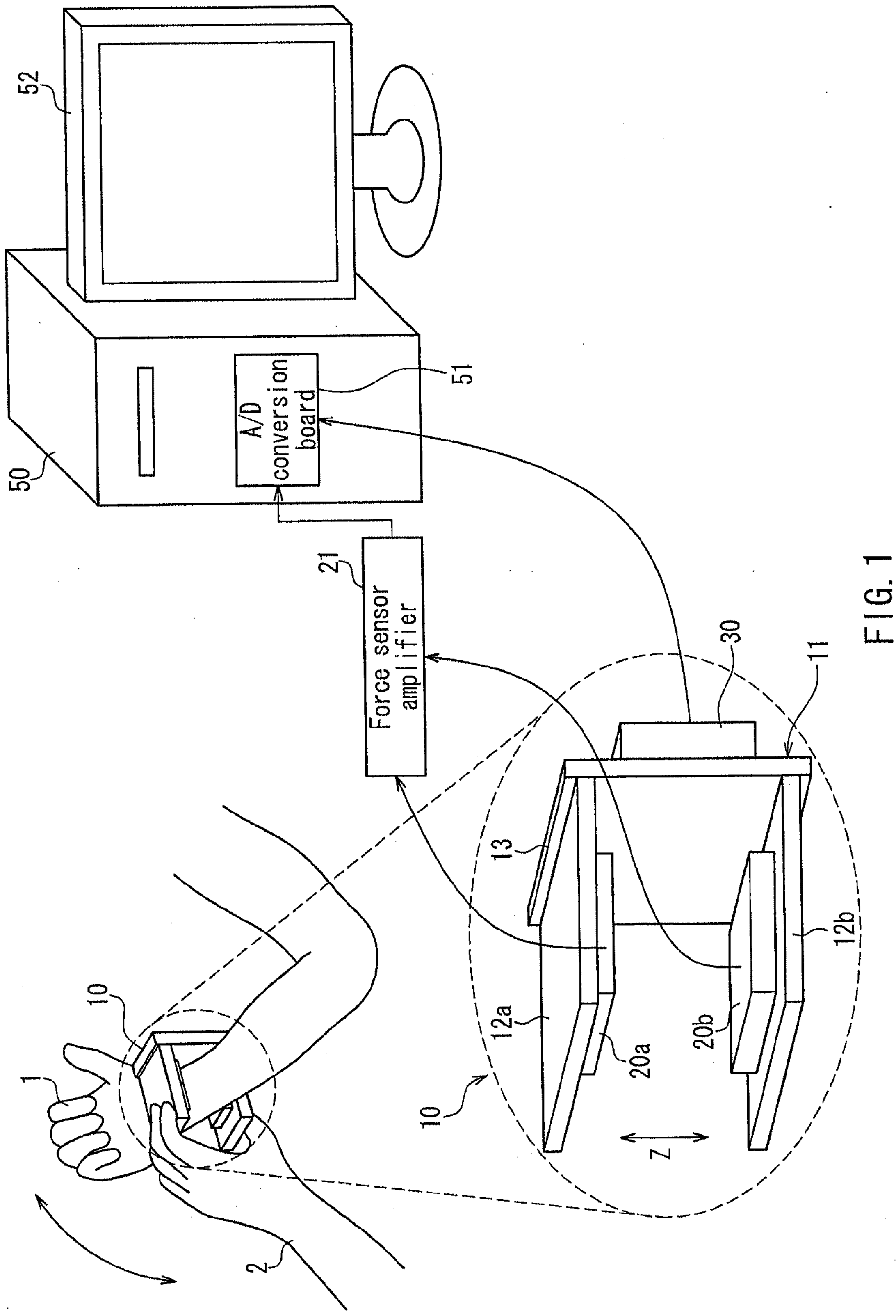
1
2
10
10
12a
20a
Z
20b
12b
13
30
11
Force sensor amplifier
21
A/D conversion board
51
50
52

FIG. 1

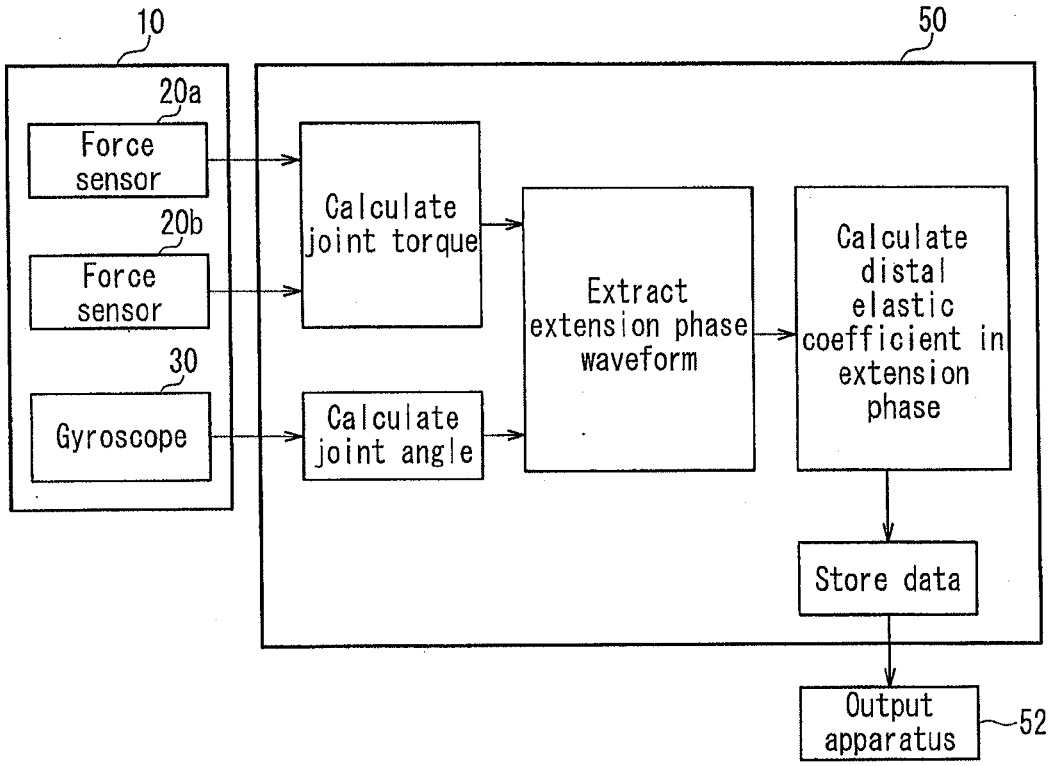
10
20a
Force sensor
20b
Force sensor
30
Gyroscope
50
Calculate joint torque
Calculate joint angle
Extract extension phase waveform
Calculate distal elastic coefficient in extension phase
Store data
Output apparatus
52

FIG. 2

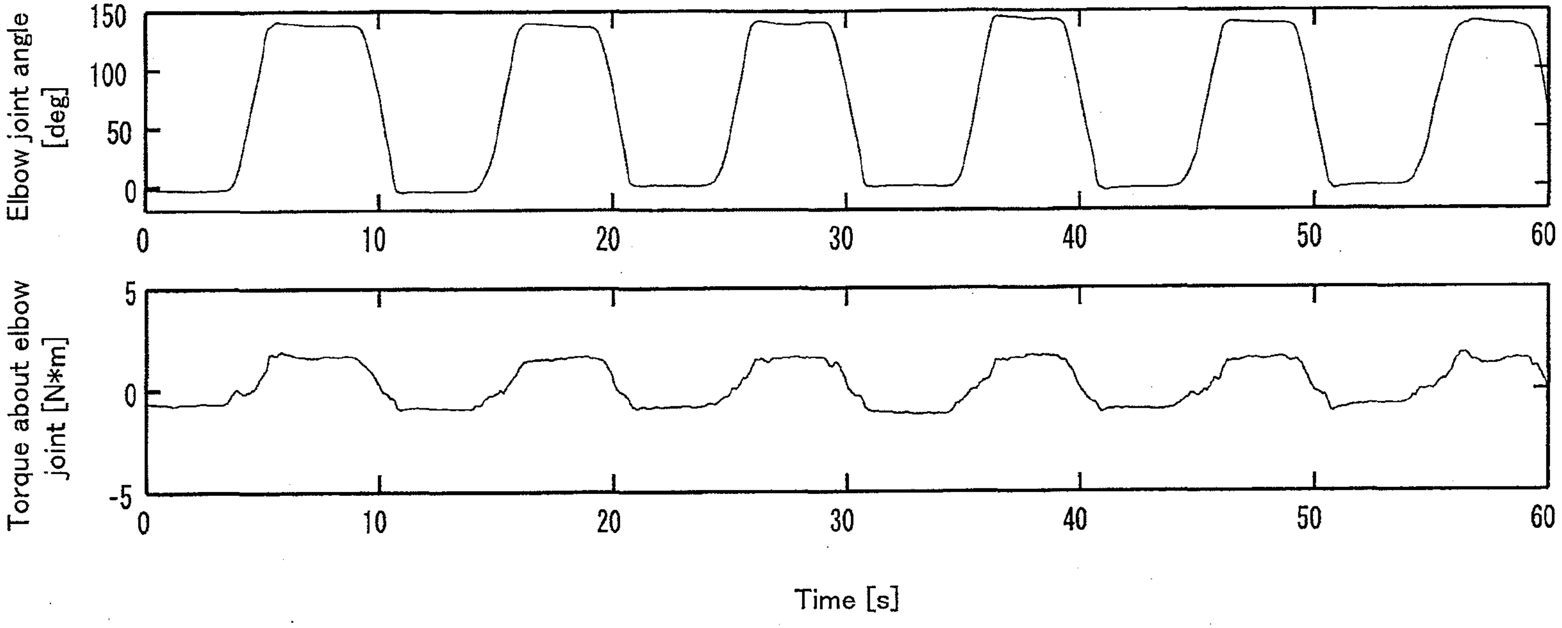
Elbow joint angle [deg]
150
100
50
0
0
10
20
30
40
50
60
Torque about elbow joint [N*m]
5
0
-5
0
10
20
30
40
50
60
Time [s]

FIG. 3

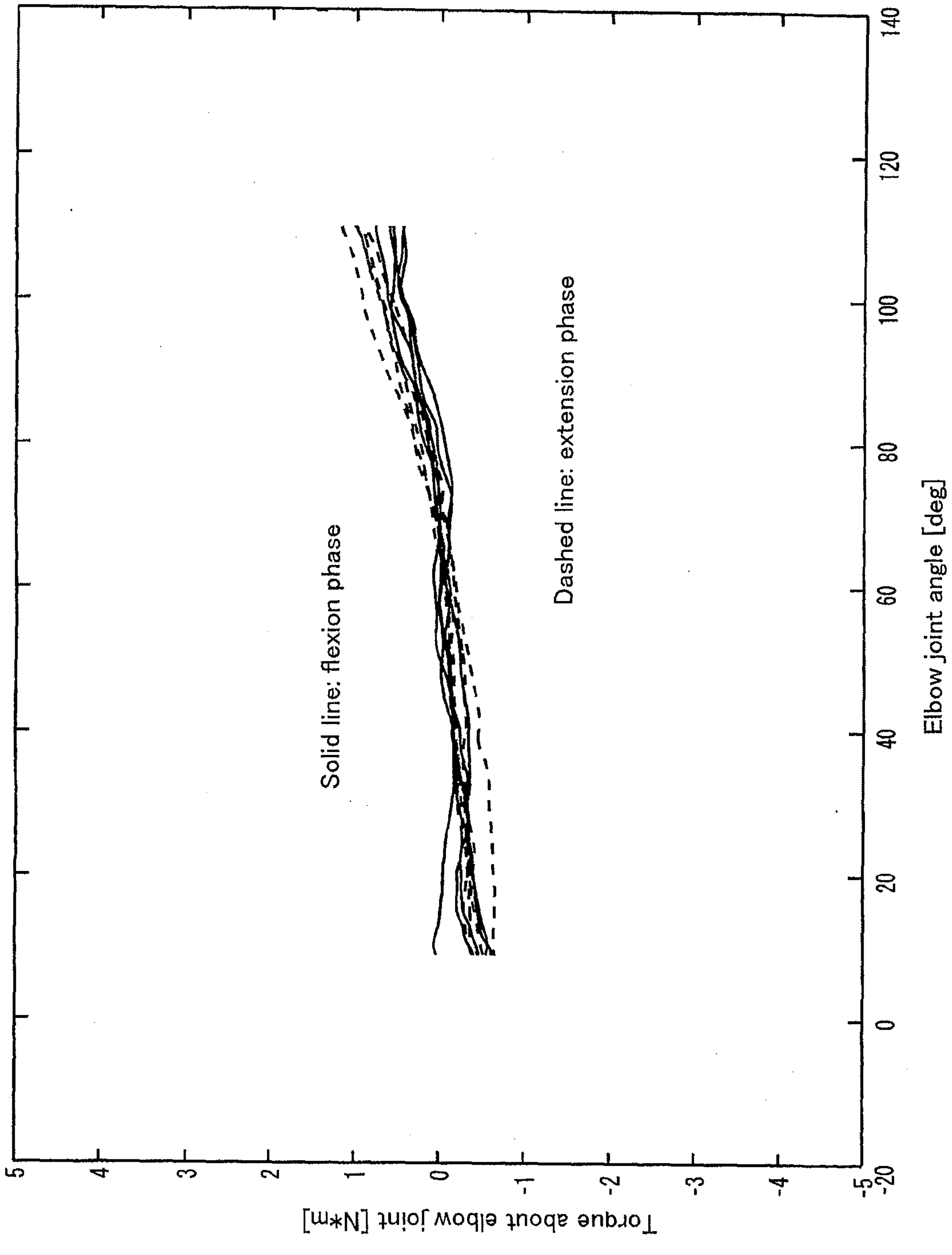
Solid line: flexion phase
Dashed line: extension phase
Torque about elbow joint [N*m]
5
4
3
2
1
0
-1
-2
-3
-4
-5
Elbow joint angle [deg]
-20
0
20
40
60
80
100
120
140

FIG. 4

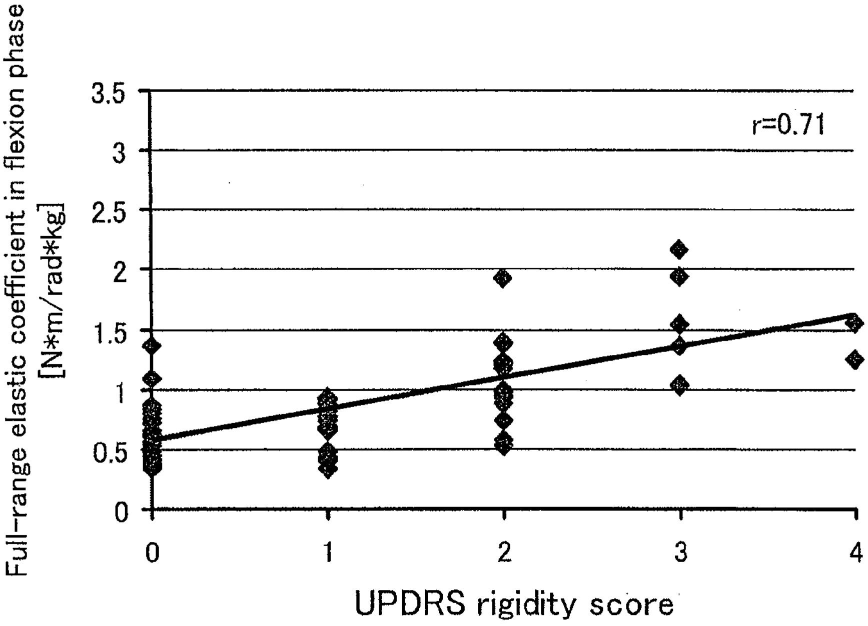
Full-range elastic coefficient in flexion phase [N*m/rad*kg]
3.5
3
2.5
2
1.5
1
0.5
0
r=0.71
0
1
2
3
4
UPDRS rigidity score

FIG. 5A

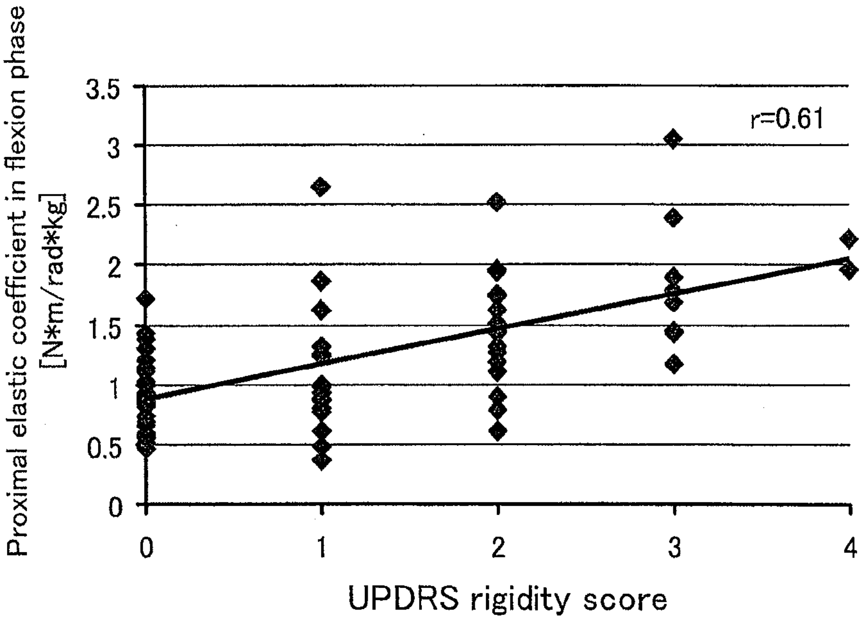
Proximal elastic coefficient in flexion phase [N*m/rad*kg]
3.5
3
2.5
2
1.5
1
0.5
0
r=0.61
0
1
2
3
4
UPDRS rigidity score

FIG. 5B

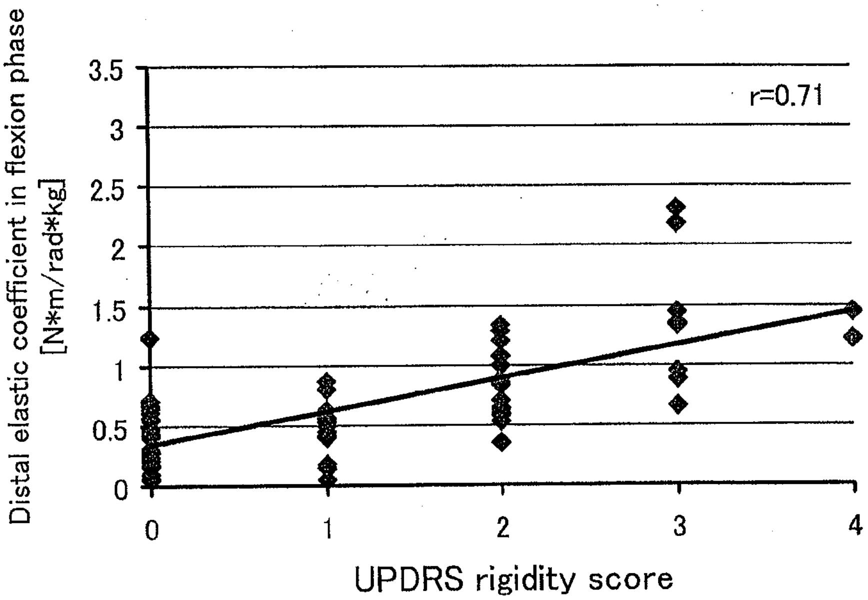
Distal elastic coefficient in flexion phase
[N*m/rad*kg]
3.5
3
2.5
2
1.5
1
0.5
0
r=0.71
0
1
2
3
4
UPDRS rigidity score

FIG. 5C

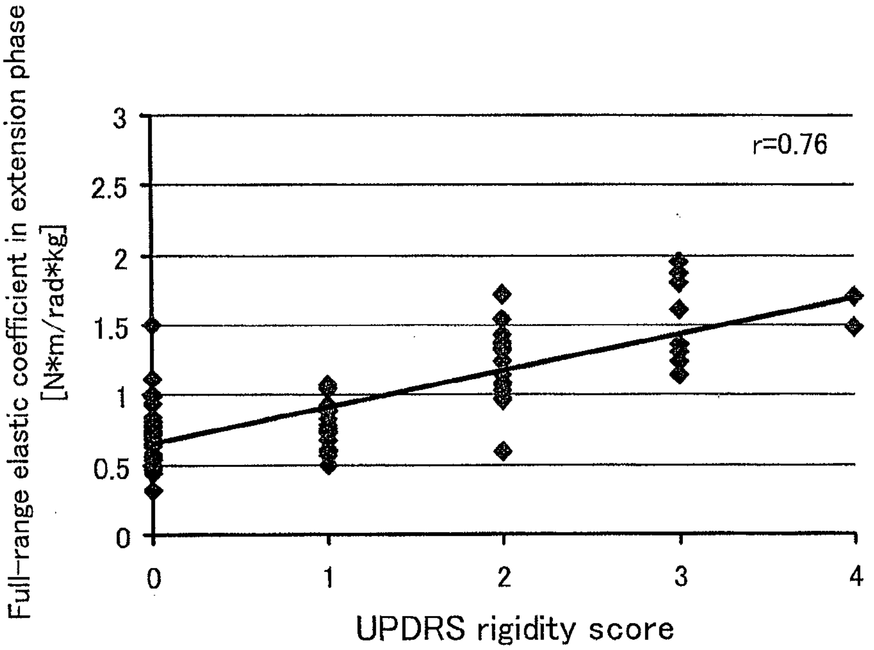
Full-range elastic coefficient in extension phase
[N*m/rad*kg]
3
2.5
2
1.5
1
0.5
0
r=0.76
0
1
2
3
4
UPDRS rigidity score

FIG. 6A

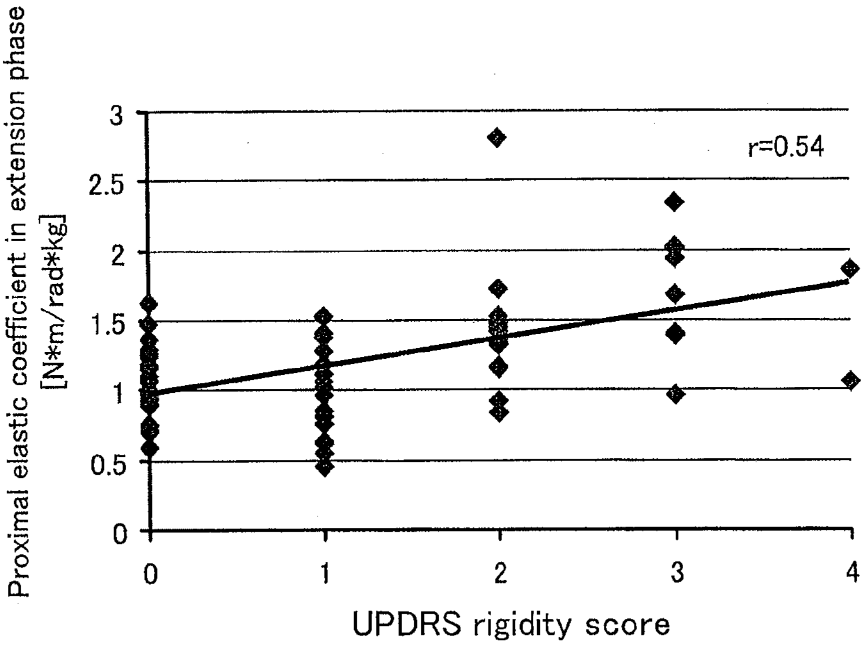
Proximal elastic coefficient in extension phase
[N*m/rad*kg]
3
2.5
2
1.5
1
0.5
0
r=0.54
0
1
2
3
4
UPDRS rigidity score

FIG. 6B

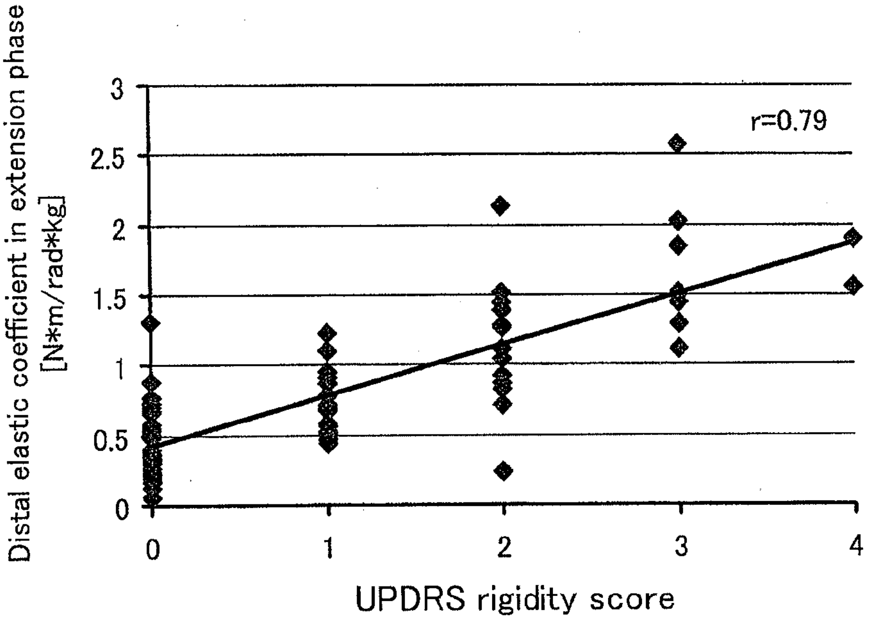
Distal elastic coefficient in extension phase
[N*m/rad*kg]
3
2.5
2
1.5
1
0.5
0
r=0.79
0
1
2
3
4
UPDRS rigidity score

FIG. 6C

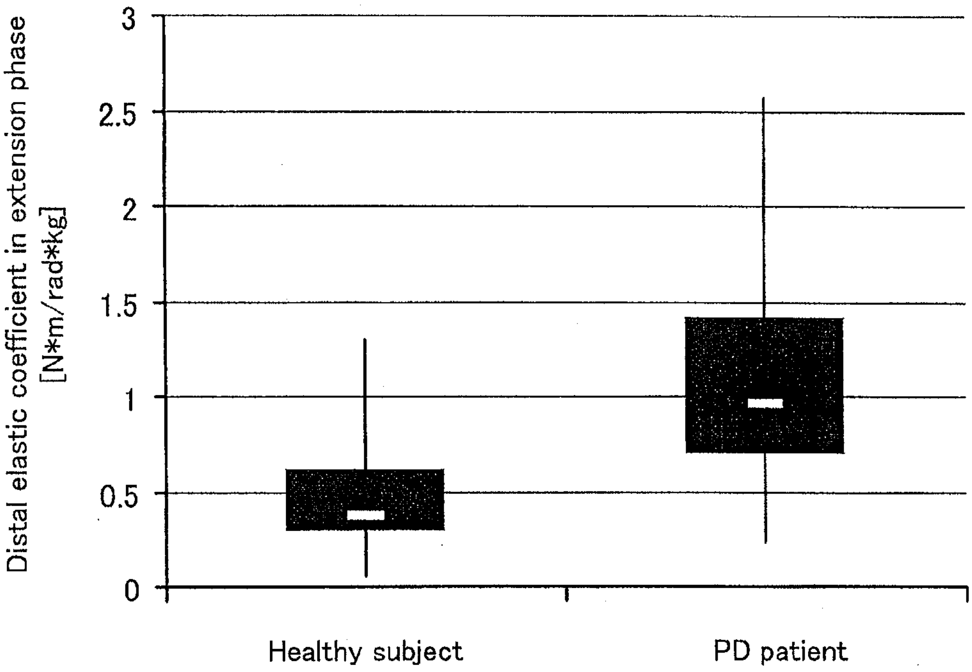
Distal elastic coefficient in extension phase
[N*m/rad*kg]
3
2.5
2
1.5
1
0.5
0
Healthy subject
PD patient

FIG. 7

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- WO 2009154117 A **[0006]**

Non-patent literature cited in the description

- Measurement of Rigidity in Parkinson's Disease. *Movement Disorders,* 1997, vol. 12 (1), 24-32 **[0004]**
- Time-course analysis of stretch reflexes in hemiparetic subjects using an on-line spasticity measurement system. *Journal of Electromyography and Kinesiology,* 2000, vol. 10, 1-14 **[0005]**

专利名称(译)	肌肉张力测量仪器		
公开(公告)号	EP2572639B1	公开(公告)日	2016-09-14
申请号	EP2011783402	申请日	2011-05-09
[标]申请(专利权)人(译)	国立大学法人大坂大学		
申请(专利权)人(译)	大阪大学		
当前申请(专利权)人(译)	大阪大学		
[标]发明人	SAKODA SABURO HAMASAKI TOSHIMITSU ENDO TAKUYUKI		
发明人	SAKODA SABURO HAMASAKI TOSHIMITSU ENDO TAKUYUKI		
IPC分类号	A61B5/107 A61B5/22 A61B5/00 A61B90/00		
CPC分类号	A61B5/4519 A61B5/1071 A61B5/224 A61B5/4082 A61B5/4528 A61B5/7239 A61B2090/066		
优先权	2010113200 2010-05-17 JP		
其他公开文献	EP2572639A4 EP2572639A1		
外部链接	Espacenet		

摘要(译)

检测单元（10）检测用于使被检体（1）的关节经历被动弯曲和伸展运动的关节角度和关节扭矩，并且运算单元（50）对来自检测单元的输出信号进行运算处理。算术单元根据关节角度将伸展阶段和屈曲阶段中的至少一个中的关节扭矩和关节角度之间的关系划分为包括近侧部分和远侧部分的两个或更多个部分，并且从远端侧部分和近端侧部分中的至少一个中的关节扭矩和关节角度之间的关系获得关节的弹性系数。这使得能够以简单的配置区分健康受试者和帕金森氏病患者，而无需测量表面肌电位。

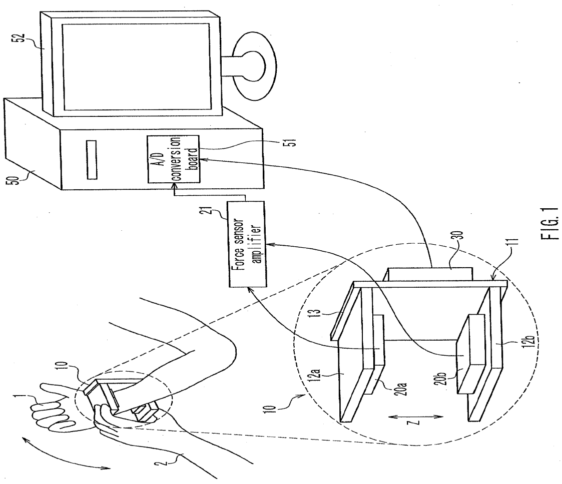

FIG. 1