



(11) EP 2 175 941 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
30.05.2012 Bulletin 2012/22

(51) Int Cl.:
A63B 24/00 (2006.01)

(21) Application number: **08789510.8**

(86) International application number:
PCT/IB2008/053079

(22) Date of filing: **31.07.2008**

(87) International publication number:
WO 2009/019638 (12.02.2009 Gazette 2009/07)

(54) Process and system for monitoring exercise motions of a person

Verfahren und System zur Überwachung von Trainingsbewegungen einer Person

Procédé et système pour surveiller les mouvements d'une exercice d'une personne

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT
RO SE SI SK TR**

(30) Priority: **08.08.2007 EP 07114021**

(43) Date of publication of application:
21.04.2010 Bulletin 2010/16

(73) Proprietors:
• **Koninklijke Philips Electronics N.V.**

5621 BA Eindhoven (NL)

Designated Contracting States:

**AT BE BG CH CY CZ DK EE ES FI FR GB GR HR
HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO
SE SI SK TR**

• **Philips Intellectual Property & Standards GmbH**
20099 Hamburg (DE)

Designated Contracting States:

DE

(72) Inventors:
• **LANFERMANN, Gerd**
NL-5656 AE Eindhoven (NL)
• **BONGERS, Edwin, G., J., M.**
NL-5656 AE Eindhoven (NL)
• **LAMBERT, Nicolaas**
NL-5656 AE Eindhoven (NL)
• **VAN ACHT, Victor, M., G.**
NL-5656 AE Eindhoven (NL)

(74) Representative: **Kroeze, Johannes Antonius Philips**
Intellectual Property & Standards
P.O. Box 220
5600 AE Eindhoven (NL)

(56) References cited:
US-A- 4 337 049 US-A- 5 372 365
US-B1- 6 778 866

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description**BACKGROUND OF THE INVENTION**

[0001] Exercising at home is a good way to gain or regain mobility and to battle conditions, for example lower back pain. A wealth of exercises is documented in books and the internet, describing the exact execution of these workouts. A majority of these exercises needs to be done in an exact way, for otherwise the movement does not stimulate or train the muscle groups that it is intended for. Controlling the execution of exercises is usually done by a trainer person. However, for home training this is not feasible.

[0002] US 6,210,301 B1 discloses a patient monitoring system, particularly for orthopedics. It is designed to be used by the medical layman and provides this person with information relating to the exercises or activities he performs. To this end, a sensor array produces sensor signals which are stored in a first memory and are compared to the contents of a second memory (ideal signal pattern). The comparison result is made available to the user via a display or as a biofeedback.

[0003] However, this system is not equipped to discriminate between important and less important sections of the exercises. For the success of an exercise it may be necessary to pay more attention to certain aspects as they might influence body mechanics and muscle function in other parts of the body as well.

[0004] US 5,372,365 describes a method and apparatus for training a user to move in a desired movement pattern, especially for training a golfer to swing a club according to the preambles of claims 1 and 7.

[0005] Despite this effort therefore there is a need in the art for a more detailed way that a person's exercises can be monitored. It is thus an object of the present invention to provide such a process and a system for monitoring exercise motions of a person.

SUMMARY OF THE INVENTION

[0006] To achieve this and other objects the present invention is directed to a process for monitoring exercise motions of a person, comprising the steps of:

- a) selecting a first sensor signal; the first sensor signal being assigned to the person and originating from a first sensor being selected from the group comprising movement sensors, physiological activity sensors, muscle activity sensors and/or respiratory sensors;
 - b) monitoring the first sensor signal and comparing the first sensor signal to a first sensor signal template;
 - c) while the first sensor signal does not deviate from the first sensor signal template by more than a pre-determined value,
- firstly monitoring signals from at least one further

sensor assigned to the person and being selected from the group comprising movement sensors, physiological activity sensors, muscle activity sensors and/or respiratory sensors;

secondly comparing the signals from the at least one further sensor to sensor signal templates representing exercises the person is performing; and

thirdly evaluating the comparison result;

d) communicating to the person undertaking the exercise when the first sensor signal deviates from the first sensor signal signal template by more than a pre-determined value; and

e) communicating to the person undertaking the exercise when the signals from the at least one further sensor deviate from the sensor signal templates representing exercises the person is performing by more than a pre-determined value.

[0007] With a system for monitoring the exercise motions according to the present invention the attention of the person is directed towards those aspects of the exercise that are especially important for the overall benefit of the exercise.

DETAILED DESCRIPTION OF THE INVENTION

[0008] Before the invention is described in detail, it is to be understood that this invention is not limited to the particular component parts of the devices described or process steps of the methods described as such devices and methods may vary. It is also to be understood that the terminology used herein is for purposes of describing particular embodiments only, and is not intended to be limiting. It must be noted that, as used in the specification and the appended claims, the singular forms "a," "an" and "the" include singular and/or plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a sensor" may include several sensors, and the like.

[0009] With respect to the process according to the present invention, step a) firstly involves selecting a first sensor signal. This first sensor signal can be seen as a lead signal. The selection can be done manually by a user or automatically. The selection is based upon the type of exercise that is to be performed and should represent one or more parameters that are important for the success of the entire exercise. For example, certain exercises require that the hip of the person remains steady. Then the first sensor signal could be a signal from a motion sensor indicating sway or rotation of the hip. In other exercises, it may be required that the person is breathing regularly or breathing in at certain parts of the exercise and breathing out at other parts. Then the first sensor signal could be a signal indicating respiratory motion of the person. Another example would be an isometric exercise where certain muscles need to be contracted throughout the exercise. Then the first sensor signal could be an electromyographical (EMG) signal from

these muscles. Depending on the type of exercise, more than one first sensor signals can be selected if this is important for the exercise.

[0010] The person carries sensors that assess his movement and, in connection with that, the orientation of the person's limbs in space. Further sensors include physiological activity sensors that can give information about the overall state of the person, for example if the person is fatigued. Muscle activity sensors determine when a muscle is contracted. Respiratory sensors determine if the person is breathing in, breathing out or holding his breath.

[0011] Step b) involves monitoring the first sensor signal and comparing the first sensor signal to a first sensor signal template. Sensor signal templates describe how the signal of the sensor should be if the exercise is performed correctly. As the exercise is performed in a certain time, the sensor template will also describe the temporal variation or non-variation of the sensor signal. A template may represent one sensor signal or a group of sensor signals. Within a group of signals in a template it still possible to access an individual signal for comparison. The comparison of the sensor signal with the template seeks to determine the amount of deviation of the real signal from the ideal signal.

[0012] In step c) a procedural loop is being executed, the loop condition being that the first sensor signal does not deviate from the first sensor signal template by more than a pre-determined value. The pre-determined value determines how much deviation from an ideal signal is regarded as acceptable so that the exercise will still be beneficial to the person.

[0013] The first step within the procedural loop is monitoring signals from at least one further sensor assigned to the person and being selected from the group comprising movement sensors, physiological activity sensors, muscle activity sensors and/or respiratory sensors. These sensors represent other actions of the person during the exercise such as moving limbs, breathing in our out or contracting muscles. In connection with the first sensor signal these sensor signals represent the actions of the person in the complete exercise.

[0014] The second step within the procedural loop is comparing the signals from the at least one further sensor to sensor signal templates representing exercises the person is performing. Deviations are also calculated in order to assess the correct execution of the exercise. The signals of the sensors within this loop as well as the first sensor signals can be recorded.

[0015] The third step within the procedural loop is evaluating the comparison result. An evaluation can be in the form of counting how often a certain movement is performed. It can also be in the form of determining how much the average deviation of the sensor signals from the templates is. As a result of the loop structure, the evaluation will only take place when the first sensor signal does not deviate from the first sensor signal template by more than a pre-determined value.

[0016] For example, in a simple exercise the lifting of an arm along a certain path while the person does not tilt his chest in the opposite direction is required. A first sensor signal could be from a sensor placed on the chest and indicating the angle of the person's longitudinal axis relative to the ground, a person standing upright in a normal fashion displaying such an angle of 90°. The sensor signal template could be that this angle is 90° throughout the exercise with a pre-determined value for acceptable deviation of 5%. The person then lifts his arm along the required path. While the person does not tilt his chest by more than the acceptable 5% the lifting of the arm is monitored by further sensors and the sensor signals are compared to the appropriate template. Furthermore, only while the person's chest is not tilted by more than the acceptable 5% a template-conforming lifting of the arm will be counted.

[0017] Steps d) and e) serve to warn the person that the exercise is not being performed correctly. The warning can be communicated to the person in the form of vibrational, optical or audio signals, for example in speech form. It is possible that the communication of step e) is only undertaken within the loop of step c), that is, that the communication of step e) will only take place as long as the first sensor signal does not deviate from the first sensor signal template by more than a pre-determined value.

[0018] An embodiment of the process according to the present invention further comprises after step e) the following step:

f) comparing the signals to a signal template and identifying whether a condition indicating the end of the exercise has been met.

[0019] To this end, the sensor signals are compared to appropriate templates. Examples for indications for the end of the exercise are that the person is standing up or that the person is lying down. It may also be determined that an exercise is over when a violation of multiple thresholds has occurred simultaneously. In general, this is advantageous as it allows for the correct execution of repetitive sets of exercises.

[0020] In a further embodiment of the process according to the present invention the exercise is determined not to have commenced if physiological data from the person exceed a pre-determined limit. The physiological data is supplied from physiological activity sensors and may be data on the pulse rate, the fact that the person is sweating, that the person's heart is beating irregularly, the person's blood pressure is too high or other indicators that further exercise is not recommended. For example, a pre-determined limit may be that the person should not exercise with a pulse rate of over 120, 130 or 140 beats per minute. In general, it can be further communicated to the person that such a pre-determined limit has been exceeded. It is advantageous to set such limits so that the person is prevented from harming himself when ex-

ercising at an inappropriate moment or when the person is already fatigued.

[0021] In a further embodiment of the process according to present invention the pre-determined value in step c), d) and/or e) varies in magnitude over the course of the exercise. This especially relates to the first sensor signal. For example, it may be determined that in the beginning phase of the exercise a deviation of a sensor signal of 10% from the ideal value is tolerable, whereas in the middle of the exercise only a deviation of 5% would still ensure an overall benefit of the exercise to the person. The variation in magnitude may apply in the same manner to all signals of the template or each signal can have its individual variation. A benefit of varying the acceptable magnitude of deviation from the ideal value is that the person can focus on the important parts of the exercise without being distracted by threshold violation warnings during less significant sections of the exercises.

[0022] In a further embodiment of the process according to the present invention the magnitude of the pre-determined value in step c), d) and/or e) is changed after the person has performed a pre-determined number of the same type of exercises. This especially relates to the first sensor signal. In general, by this the person can receive another form of training feedback. The basis of this is that the average deviation of the signals from the ideal signals is recorded for certain or all stages of the exercise. After reviewing, a therapist can then change the pre-determined value in order to reflect training success or the lack of such. For example, if the rotation of the hip during the last 10 performances of an exercise for addressing lower back pain has, in average, deviated by 10% from the ideal value and the current deviation threshold is at 15%, the therapist can manually lower the range of acceptable deviation to 10% or even less. This adaption can not only be undertaken manually, but also automatically to continuously narrow the ranges of acceptable deviation and thus to influence the person to perform the exercise more precisely.

[0023] In a further embodiment of the process according to the present invention the person further receives feedback when the end of an exercise has been recognized. The feedback can be communicated to the user in the form of vibrational, optical or audio signals, for example in speech form. The person can benefit from feedback given to him when the end of an exercise has been reached. Then the person can relax or recapitulate the past exercise.

[0024] The present invention is further directed to a system for monitoring exercise motions of a person, comprising a signal processing unit, a plurality of sensors being in communication with the signal processing unit, the sensors being selected from the group comprising movement sensors, physiological activity sensors, muscle activity sensors and/or respiratory sensors; furthermore comprising a communication unit in communication with the signal processing unit and a memory unit in communication with the signal processing unit, wherein the

memory unit comprises signal templates and ranges of acceptable deviation from the signal templates. It is possible to conduct the process for monitoring exercise of a person according to the present invention with this system.

[0025] The sensors serve to supply the system with data of the person which is needed to monitor the exercise. Examples for movement sensors are magnetometers, gyroscopes, accelerometers or integrated motion sensors where several or all of these components are combined. Examples for physiological activity sensors are electrocardiographical sensors, pulse sensors, blood oxygen sensors, blood pressure sensors, body temperature sensors and sensors measuring the electrical conductivity of the skin. These sensors provide information on the overall status of the person, for example if the person is fatigued, sweating or in state of overexertion. Muscle activity sensors can be electromyographical sensors where the contraction of a muscle is detected and measured. Respiratory sensors can be piezoelectric devices worn around the person's chest. They can sense the expansion and contraction of the person's thorax. An example would be a piezoelectric textile strip. Via wired or wireless means, the latter including infrared, bluetooth and IEEE 802.11 protocols, the sensors transmit their signals to the signal processing unit.

[0026] The signal processing unit can perform basic operations on the signals such as noise filtering and signal smoothing. It can also undertake advanced operations by calculating a representation of the person's posture and movements in the form of an avatar. The signal processing unit is equipped to monitor or process multiple sensor signals simultaneously. For example, it may process the signals of one, two, three four or five motion sensors, a pulse sensor, an electromyographical sensor and a respiratory sensor at the same time. By accessing the memory unit the signal processing unit can compare signals to templates, calculate deviations from templates and evaluate the comparison result. The evaluation could

be counting the amount of motions performed or calculating a mean deviation of the signals from the templates.

[0027] The communication unit is addressed by the signal processing unit when the person performing the exercises needs to be informed of something. The communication unit then serves the task of informing the person. For example, the person can be informed that the exercise is not done correctly. This can be in the form of vibrational, optical or audio signals. The audio signals can be simple sounds like beeps and vary their volume or frequency. By way of example, the frequency of the signal can rise in frequency the more the person's movements deviate from the ideal exercise template. The audio signals can also be speech messages giving the person detailed hints on how to exercise correctly.

[0028] A further function of the communication unit is to serve as a user interface so that the signal processing unit and the memory unit can be programmed, serviced or updated. For example, a physical therapist might ac-

cess the memory unit to observe the course of exercises of the person during regular visits or remotely via the internet. The person can also manually select a first sensor signal to be monitored.

[0029] The memory unit is also in communication with the signal processing unit. Firstly, the memory unit comprises signal templates. These templates describe how the signal of the sensor should be if the exercise is performed correctly. As the exercise is performed in a certain time, the sensor template will also describe the temporal variation or non-variation of the sensor signal. A template may represent one sensor signal or a group of sensor signals. Within a group of signals in a template it still possible to access an individual signal for comparison. For the generation of the templates they can be calculated or recorded during a supervised exercise. Furthermore, the signal templates can also reflect the situation that a person is in a starting position for beginning the exercise and the situation that the person has finished the exercise.

[0030] Furthermore, the memory unit also comprises information about how much, during the course of an exercise, the signals should be allowed to deviate from the signals representing an ideal exercise for the exercise still being able to be called successful. It is especially important for, but not limited to, signals which are selected as first signals according to the process of the invention. This is the range of acceptable deviation. The range may be stored as an individual number for the respective signals, for example permitting a deviation of 5%, 10% or 15% from the signals. The deviation may be the same or different for the signals of the various sensors. The range may also be combined with the sensor signal templates so that the sensor signals in the templates do not represent a distinct signal but rather a signal corridor.

[0031] In one embodiment of the system according to the present invention the plurality of sensors is an electromyographic sensor, a piezoelectric respiratory sensor and five motion sensors, the motion sensors each being combinations of magnetometers, gyroscopes and accelerometers. The electromyographic (EMG) sensor can be worn on the muscles of the abdomen. The piezoelectric respiratory sensor can be worn around the chest of the person undertaking the exercise to monitor the expansion and contraction of the thorax. The motion sensors can be worn on each of the lower arms and legs and, for the fifth sensor, on the hip. Such a system is well suited for monitoring exercises for addressing lower back pain where a steady breathing rhythm and the contraction of abdominal muscles while resisting torsion of the hip are important.

[0032] In a further embodiment of the system according to the present invention the sensors are in communication with the signal processing unit via the electrical conductivity of the human body. In other words, instead of a wired connection the sensors transmit their signals through the body of the person performing the exercise. It is possible for all of the sensors or only a selection of

sensors to use this means of communication. These sensors can then be viewed as being part of a body area network. An advantage of this type of communication is that the sensors use less power when transmitting their signals compared to wireless transmission and the need for wires on the person is eliminated.

[0033] A further aspect of the present invention is the use of a system according to the present invention for monitoring exercise motions of a person. The system of the present invention can especially be used in exercises addressing lower back pain.

BRIEF DESCRIPTION OF THE DRAWINGS

15 **[0034]**

Fig. 1 shows a system according to the present invention.

20 Fig. 2 shows angular data of a sensor on a person's hip

Fig. 3 shows several sensor signals in the course of performing an exercise

[0035] Referring now to Fig. 1, a system for monitoring exercise motions of a person according to the present invention is shown. The system comprises a signal processing unit 1 which is in communication with a communication unit 2. The signal processing unit 1 is also in communication with a memory unit 3. This memory unit 3 comprises signal templates 4 and also information about which range of deviation from the signal template is deemed appropriate 5. Movement sensor 6, pulse sensor 7, electromyographical sensor 8 and respiratory sensor 9 transmit their signals to the signal processing unit 1.

[0036] As Figures 2 and 3 relate to a person performing an exercise, the specific exercise shall briefly be described beforehand. The exercise is typical for a person to perform in the treatment or prevention of lower back pain. It requires the person to move a leg while maintaining the posture in the hip and controlling the breath. The first step is to kneel on the hands and the knees, with the knees under the hip and the hands underneath the shoulders. Then, while breathing in, opposite hands and feet are slid along the floor. Both hand and foot are lifted lightly. The abdominal muscles should remain contracted. Finally, while breathing out, hand and foot are returned to the starting position. This exercise requires coordination between movements, abdominal muscle contraction and breathing.

[0037] Fig. 2 shows angular data of a combined motion sensor on a person's hip while the person is performing the above-mentioned exercise. The y-axis is in the unit of angular degrees. The x-axis shows a time scale to represent the course of the experiment given in seconds.

55 Three lines are shown in the diagram. The top line, a full line, represents the sideways motion of the sensor and thus also of the person's hip. The line below that, an evenly dashed and spaced line, represents the torsion

of the sensor relative to the longitudinal axis of the person. The sensor itself is placed at the person's os sacrum. Returning to the diagram, the bottom line represents the forward and backward motion of the sensor. Up to a time of about 59 seconds into the exercise the three lines show a substantially flat profile, indicating no pronounced movement of the sensor and, in conclusion, a stable position of the hip. The trunk of the person is stable and the exercise is performed correctly. In the second half of the exercise, after about 59 seconds, the hip is raised outwards as the leg is raised. This is represented by the oscillations of the graph depicting the torsion of the sensor. In this position the person's trunk is instable and the exercise is ineffective.

[0038] Fig. 3 shows signals of a combination of sensors on the person's body during the course of a complete exercise. This can be regarded as a signal template for this exercise, grouping individual signals. The top line represents the breathing motion as the expansion and contraction of the person's chest is monitored. The solid line below represents the motion of an arm, more specifically the raising or lowering of an arm. The dotted line beneath that represents the tilt of the hip which has already been encountered in Fig. 2. The lowest line represents the level of contraction of the person's abdominal muscles. Around the lines for the hip tilt and the abdominal muscle contraction are boxes indicating the allowed range for the signal without rendering the exercise ineffective. The tilt of the hip has been selected as first sensor signal in the terminology of the process according to the present invention.

[0039] The exercise begins at the time t_1 . Then the arm is raised, the abdominal muscles are contracted and the person is breathing in. While the person is breathing in and out, the raised arm is kept at a steady height while moving the arm forward. Likewise, the tilt of the hip is kept steady, meaning that the person does not rotate the hip while extending the respective leg outwards. The tilt of the hip does not leave the boundary box around it. The contraction of the person's abdominal muscles declines steadily after the beginning of the exercise. At one point, the line leaves the boundary box. Now the exercise would not be effective anymore. However, as the range of acceptable deviation is left, a correctional feedback is given to the person, indicating that he is not trying hard enough. The exercise concludes at the time t_2 . The end of the exercise is recognized when the person completes a second cycle of breathing in and out and lowers the arm. In this example, both the rotation of the hip and the contraction of the abdominal muscles are selected as first or lead sensor signals. Therefore, at the moment the contraction of the abdominal muscles leaves its acceptable range the evaluation of the exercise is stopped and it can be determined that this performance will not count as successful.

[0040] To provide a comprehensive disclosure without unduly lengthening the specification, the applicant hereby incorporates by reference each of the patents refer-

enced above. The particular combinations of elements and features in the above detailed embodiments are exemplary only; the interchanging and substitution of these teachings with other teachings in this and the patents/

5 applications incorporated by reference are also expressly contemplated. As those skilled in the art will recognize, variations, modifications, and other implementations of what is described herein can occur to those of ordinary skill in the art without departing from the scope of the invention as claimed.

[0041] Accordingly, the foregoing description is by way of example only and is not intended as limiting. The invention's scope is defined in the following claims and the equivalents thereto. Furthermore, reference signs used 15 in the description and claims do not limit the scope of the invention as claimed.

Claims

- 20 1. A process for monitoring exercise motions of a person, comprising the steps of:
 - 25 a) selecting a first sensor signal; the first sensor signal being assigned to the person and originating from a first sensor being selected from the group comprising movement sensors (6), physiological activity sensors (7), muscle activity sensors (8) and/or respiratory sensors (9);
 - 30 b) monitoring the first sensor signal and comparing the first sensor signal to a first sensor signal template (4);
 - 35 **characterised in that** the process further comprises the steps of:
 - c) while the first sensor signal does not deviate from the first sensor signal template (4) by more than a pre-determined value, firstly monitoring signals from at least one further sensor assigned to the person and being selected from the group comprising movement sensors (6), physiological activity sensors (7), muscle activity sensors (8) and/or respiratory sensors (9);
 - 40 secondly comparing the signals from the at least one further sensor to sensor signal templates (4) representing exercises the person is performing; and
 - 45 thirdly evaluating the comparison result;
 - d) communicating to the person undertaking the exercise when the first sensor signal deviates from the first sensor signal template (4) by more than a pre-determined value; and
 - e) communicating to the person undertaking the exercise when the signals from the at least one further sensor deviate from the sensor signal templates (4) representing exercises the person is performing by more than a pre-determined value.
- 50
- 55

2. Process according to claim 1, further comprising after step e) the following step:
- f) comparing the signals to a signal template (4) and identifying whether a condition indicating the end of the exercise has been met. 5
3. Process according to claims 1 or 2, wherein the exercise is determined not to have commenced if physiological data from the person exceed a pre-determined limit. 10
4. Process according to claims 1 to 3, wherein the pre-determined value in step c), d) and/or e) varies in magnitude over the course of the exercise. 15
5. Process according to claims 1 to 4, wherein the magnitude of the pre-determined value in step c), d) and/or e) is changed after the person has performed a pre-determined number of the same type of exercises. 20
6. Process according to claims 1 to 5, wherein the person further receives feedback when the end of an exercise has been recognized. 25
7. System for monitoring exercise motions of a person, the system comprising:
- a signal processing unit (1),
a plurality of sensors being in communication with the signal processing unit, the sensors being selected from the group comprising movement sensors (6), physiological activity sensors (7), muscle activity sensors (8) and/or respiratory sensors (9);
a communication unit (2) in communication with the signal processing unit (1); and
a memory unit (3) in communication with the signal processing unit (1), wherein the memory unit (3) comprises signal templates (4) and ranges of acceptable deviation from the signal templates (5); 30
- and wherein the signal processing unit (1) is configured to: 45
- a) select a first sensor signal; the first sensor signal originating from a first one of said sensors (6, 7, 8, 9);
b) monitor the first sensor signal and compare the first sensor signal to a first sensor signal template stored in the memory unit (3); 50
- characterised in that** the signal processing unit (1) is further configured to: 55
- c) while the first sensor signal does not deviate from the first sensor signal template by more than a pre-determined value,
- firstly monitor signals from at least one further sensor in said sensors (6, 7, 8, 9);
secondly compare the signal from the at least one further sensor (6, 7, 8, 9) to sensor signal templates representing exercises the person is performing; and thirdly evaluate the comparison result;
- d) communicate, using the communication unit (2), to the person undertaking the exercise when the first sensor signal deviates from the first sensor signal template by more than a pre-determined value; and
e) communicate, using the communication unit (2), to the person undertaking the exercise when the signals from the at least one further sensor deviate from the sensor signal templates representing exercises the person is performing by more than a pre-determined value.
8. System according to claim 7, wherein the plurality of sensors is an electromyographic sensor, a piezoelectric respiratory sensor and five motion sensors, the motion sensors each being combinations of magnetometers, gyroscopes and accelerometers. 40
9. System according to claims 7 or 8, wherein the sensors are in communication with the signal processing unit (1) via the electrical conductivity of the human body. 35
10. Use of a system according to claims 7 to 9 for monitoring exercise motions of a person. 50

Patentansprüche

1. Verfahren zur Überwachung von Trainingsbewegungen einer Person, das die folgenden Schritte umfasst:
- a) Auswählen eines ersten Sensorsignals, wobei das erste Sensorsignal der Person zugeordnet ist und von einem ersten Sensor stammt, welcher aus der Gruppe ausgewählt wurde, die Bewegungssensoren (6), Sensoren für physiologische Aktivität (7), Muskelaktivitätssensoren (8) und/oder Atmungssensoren (9) umfasst;
b) Überwachen des ersten Sensorsignals und Vergleichen des ersten Sensorsignals mit einer ersten Sensorsignalvorlage (4);
dadurch gekennzeichnet, dass das Verfahren weiterhin die folgenden Schritte umfasst:
c) während das erste Sensorsignal nicht um mehr als einen vorgegebenen Wert von der ersten Sensorsignalvorlage (4) abweicht

- erstens Überwachen von Signalen von mindestens einem weiteren Sensor, der der Person zugeordnet ist und aus der Gruppe ausgewählt wurde, die Bewegungssensoren (6), Sensoren für physiologische Aktivität (7), Muskelaktivitätssensoren (8) und/oder Atmungssensoren (9) umfasst; 5
- zweitens Vergleichen der Signale von dem mindestens einen weiteren Sensor mit Sensorsignalvorlagen (4), die die von der Person ausgeführten Trainingsbewegungen darstellen; und drittens Evaluieren des Vergleichsergebnisses; 10
- d) der Person, welche die Trainingsbewegungen ausführt, mitteilen, wenn das erste Sensorsignal um mehr als einen vorgegebenen Wert von der ersten Sensorsignalvorlage (4) abweicht; und 15
- e) der Person, welche die Trainingsbewegungen ausführt, mitteilen, wenn die Signale von dem mindestens einen weiteren Sensor um mehr als einen vorgegebenen Wert von den Sensorsignalvorlagen (4) abweichen, die die von der Person ausgeführten Trainingsbewegungen darstellen. 20
- 25
2. Verfahren nach Anspruch 1, das weiterhin nach Schritt e) den folgenden Schritt umfasst:
- f) Vergleichen der Signale mit einer Signalvorlage (4) und Identifizieren, ob eine Bedingung erfüllt wurde, die das Ende der Trainingsbewegungen angibt. 30
3. Verfahren nach Anspruch 1 oder 2, wobei die Trainingsbewegung als nicht begonnen ermittelt wird, wenn physiologische Daten von der Person einen vorgegebenen Schwellenwert überschreiten. 35
4. Verfahren nach Anspruch 1 bis 3, wobei der vorgegebene Wert in Schritt c), d) und/oder e) im Laufe der Körperbewegungen in der Höhe variiert. 40
5. Verfahren nach Anspruch 1 bis 4, wobei die Höhe des vorgegebenen Wertes in Schritt c), d) und/oder e) verändert wird, nachdem die Person eine vorgegebene Anzahl von Trainingsbewegungen der gleichen Art ausgeführt hat. 45
6. Verfahren nach Anspruch 1 bis 5, wobei die Person weiterhin Rückmeldungen erhält, wenn das Ende einer Körperbewegung erkannt wurde. 50
7. System zur Überwachung von Körperbewegungen einer Person, wobei das System Folgendes umfasst: 55
- eine Signalverarbeitungseinheit (1),
eine Vielzahl von Sensoren, die mit der Signalverarbeitungseinheit in Kommunikation stehen,
wobei die Sensoren aus der Gruppe ausgewählt wurden, die Bewegungssensoren (6), Sensoren für physiologische Aktivität (7), Muskelaktivitätssensoren (8) und/oder Atmungssensoren (9) umfasst; 60
- eine Kommunikationseinheit (2), die mit der Signalverarbeitungseinheit (1) in Kommunikation steht; und 65
- eine Speichereinheit (3), die mit der Signalverarbeitungseinheit (1) in Kommunikation steht, wobei die Speichereinheit (3) Signalvorlagen (4) und Bereiche akzeptabler Abweichung von den Signalvorlagen (5) umfasst; 70
- und wobei die Signalverarbeitungseinheit (1) konfiguriert ist, um
- a) ein erstes Sensorsignal auszuwählen, wobei das erste Sensorsignal von einem ersten der genannten Sensoren (6, 7, 8, 9) stammt; 75
- b) das erste Sensorsignal zu überwachen und das erste Sensorsignal mit einer ersten in der Speichereinheit (3) gespeicherten Sensorsignalvorlage zu vergleichen; 80
- dadurch gekennzeichnet, dass** die Signalverarbeitungseinheit (1) weiterhin konfiguriert ist, um:
- c) während das erste Sensorsignal nicht um mehr als einen vorgegebenen Wert von der ersten Sensorsignalvorlage abweicht 85
- Signale von mindestens einem weiteren Sensor der genannten Sensoren (6, 7, 8, 9) zu überwachen; 90
- zweitens das Signal von dem mindestens einen weiteren Sensor (6, 7, 8, 9) mit Sensorsignalvorlagen zu vergleichen, die die von der Person ausgeführten Trainingsbewegungen darstellen; und 95
- drittens das Vergleichsergebnis zu evaluieren;
- d) der Person, welche die Trainingsbewegungen ausführt, mittels der Kommunikationseinheit (2) mitzuteilen, wenn das erste Sensorsignal um mehr als einen vorgegebenen Wert von der ersten Sensorsignalvorlage abweicht; und 100
- e) der Person, welche die Trainingsbewegungen ausführt, mittels der Kommunikationseinheit (2) mitzuteilen, wenn die Signale von dem mindestens einen weiteren Sensor um mehr als einen vorgegebenen Wert von den Sensorsignalvorlagen abweichen, die die von der Person ausgeführten Trainingsbewegungen darstellen.

8. System nach Anspruch 7, wobei die Vielzahl von Sensoren ein elektromyographischer Sensor, ein piezoelektrischer Atemsensor und fünf Bewegungssensoren umfasst, wobei die Bewegungssensoren jeweils Kombinationen aus Magnetometern, Gyroskopen und Beschleunigungsmessern sind.
9. System nach Anspruch 7 oder 8, wobei die Sensoren über die elektrische Leitfähigkeit des menschlichen Körpers in Kommunikation mit der Signalverarbeitungseinheit (1) stehen.
10. Verwendung eines Systems nach Anspruch 7 bis 9 zur Überwachung von Trainingsbewegungen einer Person.

Revendications

1. Procédé de surveillance des mouvements d'exercice d'une personne, comprenant les étapes consistant à :

a) sélectionner un premier signal de capteur ; le premier signal de capteur étant attribué à la personne et provenant d'un premier capteur sélectionné dans le groupe comprenant des capteurs de mouvement (6), des capteurs de l'activité physiologique (7), des capteurs de l'activité musculaire (8) et/ou des capteurs de respiration (9) ;
 b) surveiller le premier signal de capteur et comparer le premier signal de capteur à un premier modèle de signal de capteur (4) ;

caractérisé en ce que le procédé comprend en outre les étapes consistant à :

c) alors que le premier signal de capteur ne s'écarte pas du premier modèle de signal de capteur (4) de plus d'une valeur prédéterminée, premièrement surveiller des signaux d'au moins un autre capteur attribué à la personne et sélectionné dans le groupe comprenant des capteurs de mouvement (6), des capteurs de l'activité physiologique (7), des capteurs de l'activité musculaire (8) et/ou des capteurs de respiration (9) ;

deuxièmement comparer les signaux de l'au moins un autre capteur aux modèles de signal de capteur (4) représentant les exercices que la personne est en train d'effectuer ; et troisièmement évaluer le résultat de comparaison ;

d) communiquer à la personne qui fait l'exercice quand le premier signal de capteur s'écarte du premier modèle de signal de capteur (4) de plus d'une valeur prédéterminée ; et

e) communiquer à la personne qui fait l'exercice quand les signaux de l'au moins un autre cap-

5

10

15

20

25

30

35

40

45

50

55

teur s'écartent des modèles de signal de capteur (4) représentant les exercices que la personne est en train d'effectuer de plus d'une valeur pré-déterminée.

2. Procédé selon la revendication 1, comprenant en outre après l'étape e) l'étape suivante consistant à :

f) comparer les signaux à un modèle de signal (4) et identifier si une condition indiquant la fin de l'exercice est remplie.

3. Procédé selon les revendications 1 ou 2, dans lequel il est établi que l'exercice n'a pas commencé si les données physiologiques de la personne dépassent une limite pré-déterminée.

4. Procédé selon les revendications 1 à 3, dans lequel la valeur pré-déterminée dans l'étape c), d) et/ou e) varie en amplitude au cours de l'exercice.

5. Procédé selon les revendications 1 à 4, dans lequel l'amplitude de la valeur pré-déterminée dans l'étape c), d) et/ou e) est modifiée après que la personne a réalisé un nombre pré-déterminé du même type d'exercices.

6. Procédé selon les revendications 1 à 5, dans lequel la personne reçoit en outre un feedback lorsque la fin d'un exercice a été détectée.

7. Système de surveillance des mouvements d'exercice d'une personne, le système comprenant :

une unité de traitement de signal (1), une pluralité de capteurs qui sont en communication avec l'unité de traitement de signal, les capteurs étant sélectionnés dans le groupe comprenant des capteurs de mouvement (6), des capteurs de l'activité physiologique (7), des capteurs de l'activité musculaire (8) et/ou des capteurs de respiration (9) ;
 une unité de communication (2) en communication avec l'unité de traitement de signal (1) ; et une unité de mémoire (3) en communication avec l'unité de traitement de signal (1), dans lequel l'unité de mémoire (3) comprend des modèles de signal (4) et des plages d'écart acceptable des modèles de signal (5) ;
 et dans lequel l'unité de traitement de signal (1) est configurée pour :

a) sélectionner un premier signal de capteur ; le premier signal de capteur provenant d'un premier desdits capteurs (6, 7, 8, 9) ;

b) surveiller le premier signal de capteur et comparer le premier signal de capteur à un

premier modèle de signal de capteur enregistré dans l'unité de mémoire (3) ;

caractérisé en ce que l'unité de traitement de signal (1) est configurée en outre pour : 5

c) alors que le premier signal de capteur ne s'écarte pas du premier modèle de signal de capteur de plus d'une valeur prédéterminée, 10

premièrement surveiller des signaux d'au moins un autre capteur parmi lesdits capteurs (6, 7, 8, 9) ;

deuxièmement comparer le signal de l'au moins un autre capteur (6, 7, 8, 9) aux modèles de signal de capteur représentant les exercices que la personne est en train d'effectuer ; et troisièmement évaluer le résultat de comparaison ; 20

d) communiquer, à l'aide de l'unité de communication (2), à la personne qui fait l'exercice quand le premier signal de capteur s'écarte du premier modèle de signal de 25 capteur de plus d'une valeur prédéterminée ; et

e) communiquer, à l'aide de l'unité de communication (2), à la personne qui fait l'exercice quand les signaux de l'au moins un autre capteur s'écartent des modèles de signal de capteur représentant les exercices que la personne est en train d'effectuer de plus d'une valeur prédéterminée. 35

8. Système selon la revendication 7, dans lequel la pluralité de capteurs est un capteur électromyographique, un capteur de respiration piézoélectrique et cinq capteurs de mouvement, les capteurs de mouvement étant chacun des combinaisons de magnétomètres, gyroscopes et accéléromètres. 40

9. Système selon les revendications 7 ou 8, dans lequel les capteurs sont en communication avec l'unité de traitement de signal (1) via la conductivité électrique 45 du corps humain.

10. Utilisation d'un système selon les revendications 7 à 9 pour surveiller les mouvements d'exercice d'une personne. 50

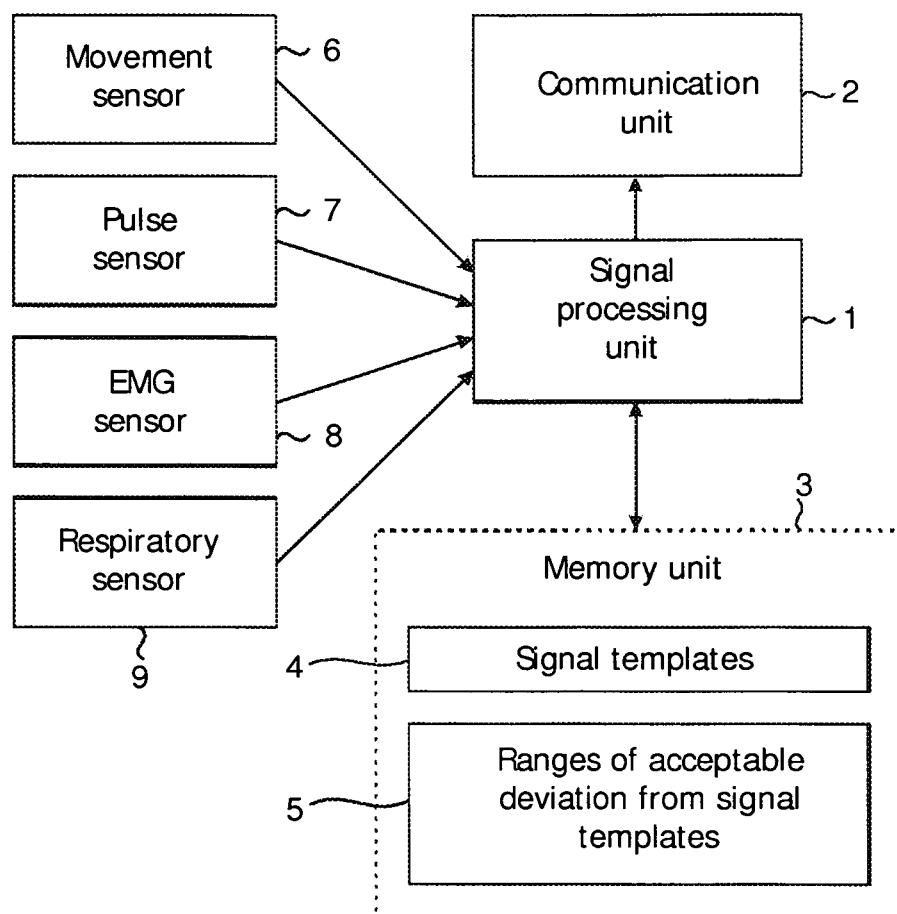


FIG. 1

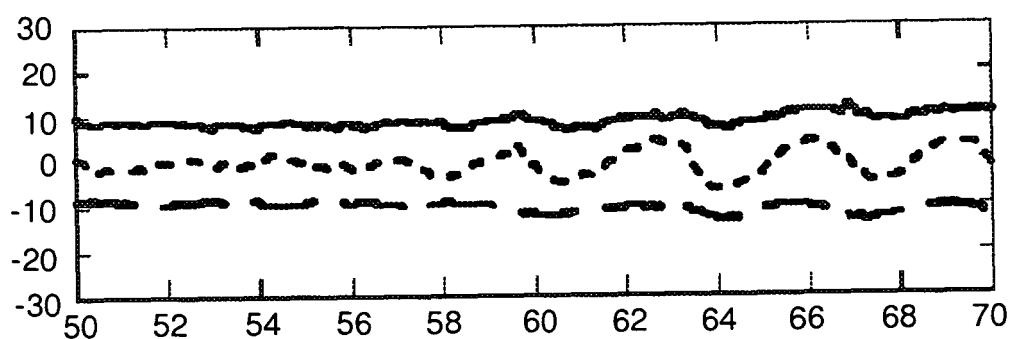


FIG. 2

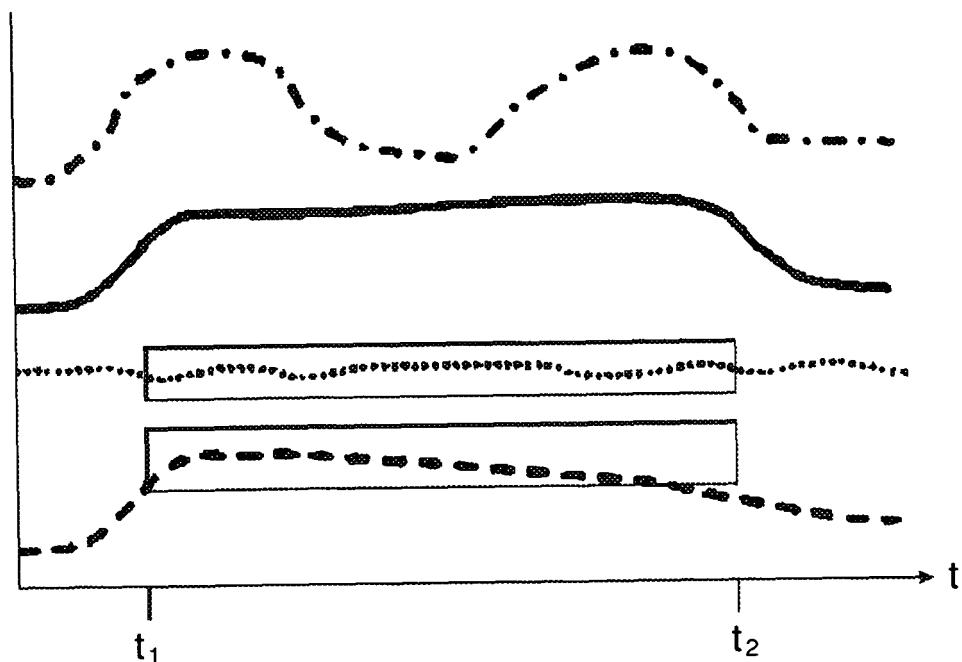


FIG. 3

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 6210301 B1 [0002]
- US 5372365 A [0004]



⑩ A **Terinzagelegging** ⑪ 8203228

Nederland

⑯ NL

④ Inrichting voor het meten van een spierkracht.

⑤ Int.Cl.: G01L 5/02.

⑦ Aanvrager: Ronald Christiaan de Buck te Tilburg.

⑧ Gem.: Ir. P.N. Hoorweg c.s.
Octrooibureau Arnold & Siedsma
Willemsstraat 13
4811 AH Breda.

⑨ Aanvraag Nr. 8203228.

⑩ Ingediend 17 augustus 1982.

⑪ --

⑫ --

⑬ --

⑭ --

⑮ --

⑯ Ter inzage gelegd 16 maart 1984.

De aan dit blad gehechte stukken zijn een afdruk van de oorspronkelijk ingediende beschrijving met conclusie(s) en eventuele tekening(en).

Inrichting voor het meten van een spierkracht.

De uitvinding heeft betrekking op een inrichting voor het meten van een door spieren van een lichaamsdeel, zoals arm-, been-, rug- of buikspieren, uitgeoefende kracht.

5 Het doel van de uitvinding is om een inrichting te verschaffen waarmee elke spier afzonderlijk nauwkeurig kan worden gemeten door het elimineren van storende invloeden.

10 De inrichting volgens de uitvinding onderscheidt zich door een gestel, een door het gestel gedragen steunvlak voor het steunen van de te meten persoon, een subframe met op afstand van het steunvlak aangebracht reactievlak, welk subframe via een meetelement met het gestel is verbonden. Door de te meten persoon een kracht tussen het 15 steunvlak en het reactievlak te laten uitoefenen met het te meten lichaamsdeel, kan de spierkracht van dat lichaamsdeel doeltreffend worden gemeten.

Teneinde een verplaatsing van het reactievlak ten opzichte van het steunvlak tijdens de meting minimaal te houden, hetgeen een verandering van het lichaam van de te 20 meten persoon voorkomt, is het meetelement voorzien van tenminste een in een electrische keten opgenomen rekstrook.

Bij voorkeur bestaat het meetelement uit een rechthoekig blok met twee parallelle bevestigingseindvlakken, 25 waarbij tussen de eindvlakken rekstroken symmetrisch ten opzichte van het middenlangsvlak van het blok zijn aangebracht. Hiermee kan worden verzekerd dat slechts vervormingen ten gevolge van een zuivere druk- of afschuifkracht kunnen worden 30 gemeten en de vervormingsinvloeden ten gevolge van buiging kunnen worden geelimineerd. Dit verzekert een reproduceerbare meting.

In de voorkeursuitvoeringsvorm is het blok voorzien van een zich tussen de eindvlakken uitstrekende sleufvormige ruimte, waarin een loodrecht op de eindvlakken staand wanddeel voor het opbrengen van de rekstroken vast is
5 aangebracht. Hiermee kan de ruimtelijke orientatie van de rekstroken ten opzichte van de krachtrichting en het gestel respectievelijk subframe gemakkelijk worden bepaald, waardoor de optimale positie voor de meting is verzekerd.

Teneinde de inrichting aan te passen aan de
10 verschillende lengtes van de proefpersonen is het steunvlak en/of het reactievlek instelbaar aangebracht.

Bovengenoemde en andere kenmerken van de uitvinding worden nader toegelicht aan de hand van de hieronderstaande figuurbeschrijving, waarvan een tweetal uitvoerings-
15 voorbeelden. In de tekening toont:

figuur 1 een perspectivisch aanzicht van een eerste uitvoeringsvorm van de inrichting volgens de uitvinding,

figuur 2 een perspectivisch aanzicht van een tweede uitvoeringsvorm van de inrichting,

figuur 3 een perspectivisch aanzicht van een in de voornoemde uitvoeringen toegepast meetelement.

In figuur 1 is met het referentiecijfer 1 een uit buis en profielmateriaal vervaardigd gestel aangegeven.
25 Bovenop het gestel 1 zijn een tweetal parallelle geleidingsstaven 2 aangebracht, waarlangs een sledge 3, door middel van glijlagers 4 heen en weer verschuifbaar is. De stand van de sledge is instelbaar door middel van een in het gestel 1 gelagerde schroefspil 5, die door middel van een handwiel 6
30 draaibaar is. Een aan de onderzijde van de sledge 3 aangebracht, niet zichtbaar moerorgaan werkt samen met de schroefdraad van spil 5.

Op de sledge is een steun in de vorm van een stoel 7 aangebracht voor het opnemen van de te meten persoon.

35 De sledge 3 is tevens voorzien van een in hoogte verstelbaar hulpframe 8, waarbij de verstelling kan

plaatsvinden door middel van een met een handwiel 9 verdraaibare schroefspil 10. Het hulpframe 10 bestaat uit een tweetal parallelle, boven elkaar aangebrachte buisprofielen, waarin telescopisch buisprofielen 11 dwars op het frame 1 verplaatsbaar zijn. De verplaatsing komt tot stand door middel van een in de buizen opgenomen door een handwiel 12 bediende schroefspil 13. Het hulpframe is voorzien van een bevestigingsplaat 14 voor het aanbrengen van een meetorgaan 15, aan de andere zijde waarvan een subframe 16 is aangebracht in de vorm van een u. De plaats in de lengte van het u-vormige subframe 16 is zodanig dat deze zich als armleuningen aan weerszijden naast de stoel 7 uitstrekken.

Het subframe 16 is voorzien van een daarlangs verschuifbare mof 17.

Tegenover de stoel 7 is een reactievlak in de vorm van een voetplaat 18 aangebracht, welke plaat is bevestigd op een tweede subframe 19. Het tweede subframe 19 is via meetelementen 15 draaibaar verbonden met een lager 20 op het uiteinde van de glijstaven 2. De voetplaat 18 respectievelijk het subframe 19 is derhalve draaibaar om de as A-A verbonden met het gestel 1.

De meetelementen 15, welke hieronder nog nader worden toegelicht, zijn voorzien van rekstroken welke zijn opgenomen in een electrische meetketen voor het waarnemen en verwerken van de te meten spierkracht, hetwelk door een niet getoonde afleeseenheid direct aan de gebruiker kan worden doorgegeven.

De instelling en werking van de inrichting is als volgt.

De te meten persoon neemt plaats in de stoel 7, en stelt voor het meten van de spierkracht in de benen de voeten tegen de voetplaat 18. De afstand tussen stoel 7 en voetplaat 18 kan vervolgens worden ingesteld teneinde de gewenste hoek tussen onder en bovenbeen te verkrijgen. De te meten persoon drukt vervolgens met beide benen krachtig tegen de voetplaat 18, waardoor de meetelementen 15 een bepaalde

vervorming ondergaan hetgeen wordt geregistreerd in de elektrische verwerkingsketen.

Voor het meten van de linker of rechter armspieren, kan de persoon de onderarm onder de huls 17 voeren en vervolgens deze krachtig omhoogtrekken. De instelling wat betreft de juiste hoogte en breedte van de subframes 16 ten opzichte van de stoel 7 worden daarbij vooraf ingesteld door middel van de handwielen 9 respectievelijk 12. De huls 17 kan vrij over het subframe 16 worden verschoven teneinde de richting aan te passen aan de lengte van de onderarm. De op elk subframe uitgeoefende kracht wordt waargenomen door het meetelement 15.

Figuur 2 toont een tweede uitvoeringsvorm geschikt voor het meten van de rug- respectievelijk buikspierkrachten van de te meten persoon. De inrichting bestaat ook hier uit een buisvormig gestel 25 dat aan de onderzijde is voorzien door middel van de cylinder 26 in hoogte verstelbare voetplaat 27, waarop de persoon staande kan plaatsnemen. Het gestel is tevens voorzien van een verticaal steunvlak 28, terwijl aan de bovenzijde een om de as B-B zwenkbaar subframe 29 is aangebracht. Het subframe bestaat uit twee parallelle tandheugels 30, waarlangs een van een reactievak 31 voorzien staaf 32 door middel van een handwiel 33 verschuifbaar is. Het subframe is via meetelementen 15 aan het gestel gekoppeld welke meetelementen zich symmetrisch ter weerszijden van het steunvlak 28 bevinden. Het subframe 29 is om de as B-B omhoog zwenkbaar teneinde de toegankelijkheid van de inrichting mogelijk te maken. In de getekende stand steunt de staven 30 verbinding dwarsstaaf op een uitstekende steunarm 34 van het gestel 25. Het gewicht van het subframe 29 wordt gecompenseerd door een stel gasveren 35 tussen het gestel 25 en het subframe 29.

De bovenbeschreven inrichting werkt als volgt. Na het plaatsnemen van de persoon op de voetplaat 27 wordt deze zover omhoog bewogen dat bijvoorbeeld de borst zich tegenover de reactieplaats 31 bevindt. De rugzijde steunt tegen

de verticale steunplaat 28. Door de reactieplaat 31 tegen de borst te plaatsen kan de te meten persoon met de borst de plaat 31 wegdrukken, waardoor de meetelementen 15 worden belast via het subframe 29. Op deze wijze zijn de buikspieren 5 van de persoon te meten. Door 180° te draaien kunnen van de persoon de rugspieren worden gemeten.

Door met de beide handen tegen de reactieplaat 31 te drukken kunnen beide armsgpieren worden gemeten.

Figuur 3 toont een voorkeursuitvoeringsvorm 10 van een meetelement 15, dat bestaat uit een massief blok van geschikt materiaal, bijvoorbeeld aluminium, aan welk blok een tweetal parallelle eindvlakken 40 zich bevinden maar die dienen voor het bevestigen aan enerzijds het gestel en anderzijds het subframe. Het blok is uitgevoerd met een sleufvormige opening 41, dat door middel van een vingerfrees kan worden verkregen. In het midden van de sleufvormige opening 41 is een wanddeel 42 overgebleven, zodanig dat de naar de vlakken 40 toegekeerde einden vrij van het materiaal van het blok 15 ligt. Slechts de boven- en onderrand van een wand 42 voor 15 men derhalve een hechte verbinding met het blok. Aan een of beide zijden van de wand 42 zijn rekstroken 43 aangebracht 20 welke in een willekeurige configuratie overeenkomend met de gewenste meting zijn geplaatst.

Het getoonde blok biedt het voordeel dat bij 25 een belasting met een kracht F slechts de afschuifspanning op de wand 42 door middel van de rekstroken wordt gemeten. Alle overige storende invloeden als buigmoment of krachten dwars op de getoonde vector F worden geelimineerd. Een dergelijk blok kan derhalve in elke willekeurige plaats van beide hierboven beschreven inrichtingen worden toegepast. Zo is bijvoorbeeld bij het subframe 16 het de gebruiker toegestaan om 30 ook krachten uit te oefenen in de richting van de stoel 7, die door het getoonde blok niet worden gemeten. Slechts de zuivere verticale kracht wordt gemeten. Ook de plaats van de huls 35 17 is hierdoor niet meer belangrijk omdat de spanningen ten-

gevolge van het buigend moment zijn geelimineerd, aangezien de wand 42 nabij de neutrale lijn in het blok 15 ligt.

Bij de voetplaat 18 uit figuur 1 is dankzij de zwenkbare opstelling rond de lijn A-A altijd de zuivere dwarskracht parallel aan de wand 42 gemeten. Hetzelfde geldt voor de beide meetelementen 15 bij het subframe 29 in de uitvoeringsvorm volgens figuur 2.

De uitvinding is niet beperkt tot de hierboven beschreven uitvoeringsvormen.

C O N C L U S I E S

1. Inrichting voor het meten van een door spieren van een lichaamsdeel, zoals arm-, been-, rug- of buikspieren, uitgeoefende kracht, gekenmerkt door een gestel, een door het gestel gedragen steunvlak voor het steunen van de te meten persoon, een subframe met op afstand van het steunvlak aangebracht reactievlak, welk subframe via een meetelement met het gestel is verbonden.

2. Inrichting volgens conclusie 1, met het kenmerk, dat het meetelement is voorzien van tenminste een in een elektrische keten opgenomen rekstrook.

3. Inrichting volgens conclusie 1 of 2, met het kenmerk, dat het meetelement bestaat uit een rechthoekig blok met twee parallelle bevestigingseindvlakken, waarbij tussen de eindvlakken rekstroken symmetrisch ten opzichte van een middenlangsvlak van het blok is aangebracht.

4. Inrichting volgens conclusie 1-3, met het kenmerk, dat het blok is voorzien van zich tussen de eindvlakken uitstrekende, sleufvormige ruimten, waarin een loodrecht op de eindvlakken staand wanddeel voor het opbrengen van de rekstroken vast is aangebracht.

5. Inrichting volgens conclusie 1-4, met het kenmerk, dat het wanddeel samenvalt met het middenlangsvlak van het blok.

6. Inrichting volgens conclusie 1-5, met het kenmerk, dat het wanddeel loodrecht of nagenoeg loodrecht staat op het reactie vlak van het subframe.

7. Inrichting volgens een der voorgaande conclusies, met het kenmerk, dat het subframe als een u-vormige beugel is uitgevoerd waarlangs een, het reactievlak dragende huls schuifbaar is.

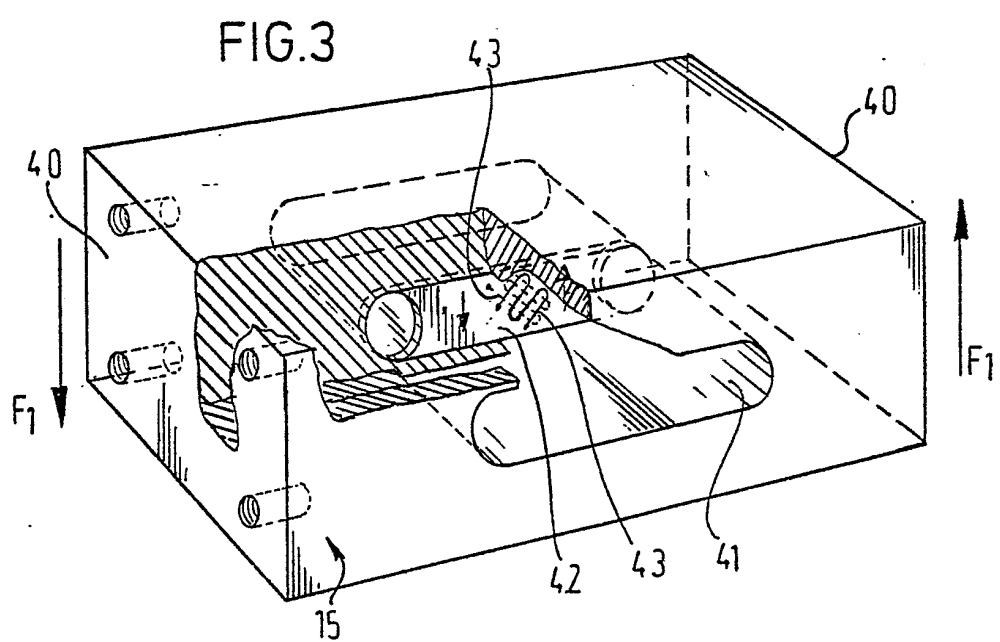
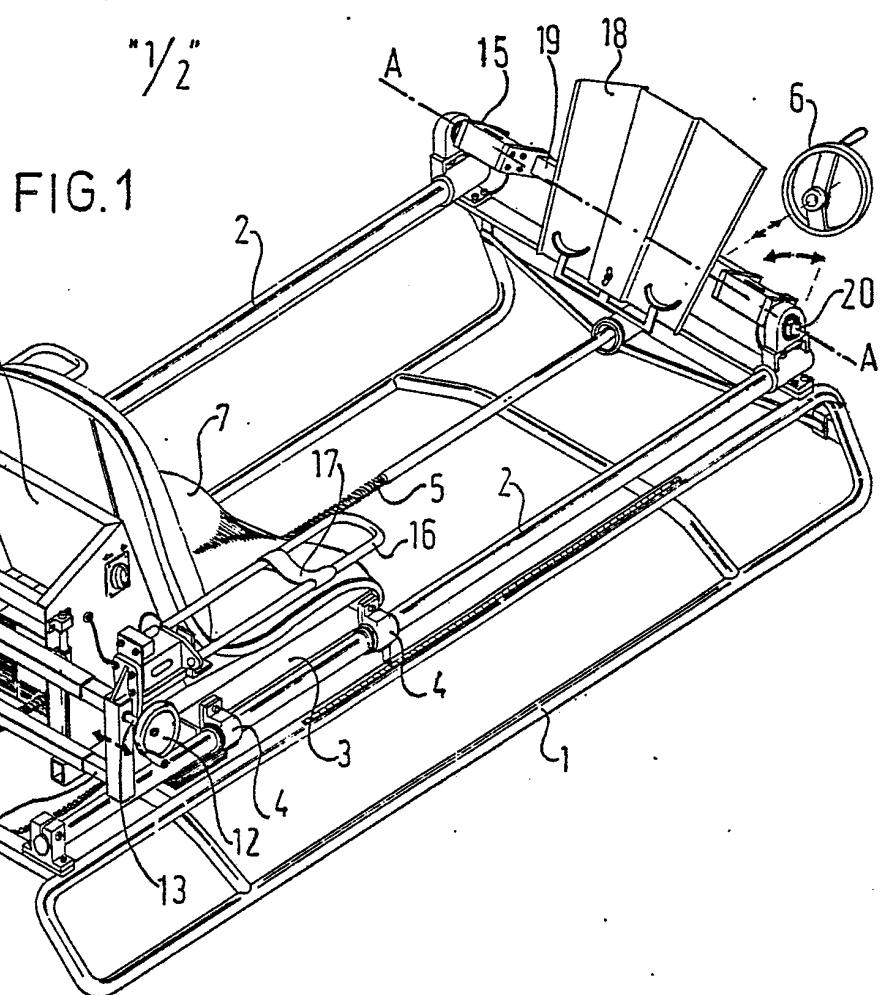
8. Inrichting volgens een der voorgaande con-

clusies 1-6, met het kenmerk, dat het subframe om een as scharnierend met het gestel is verbonden.

9. Inrichting volgens conclusie 8, met het kenmerk, dat de scharnieraas in het de rekstroken dragende 5 wandvlak ligt.

10. Inrichting volgens een der voorgaande conclusies, met het kenmerk, dat het steunvlak en/of reactievvlak instelbaar zijn (is) aangebracht.

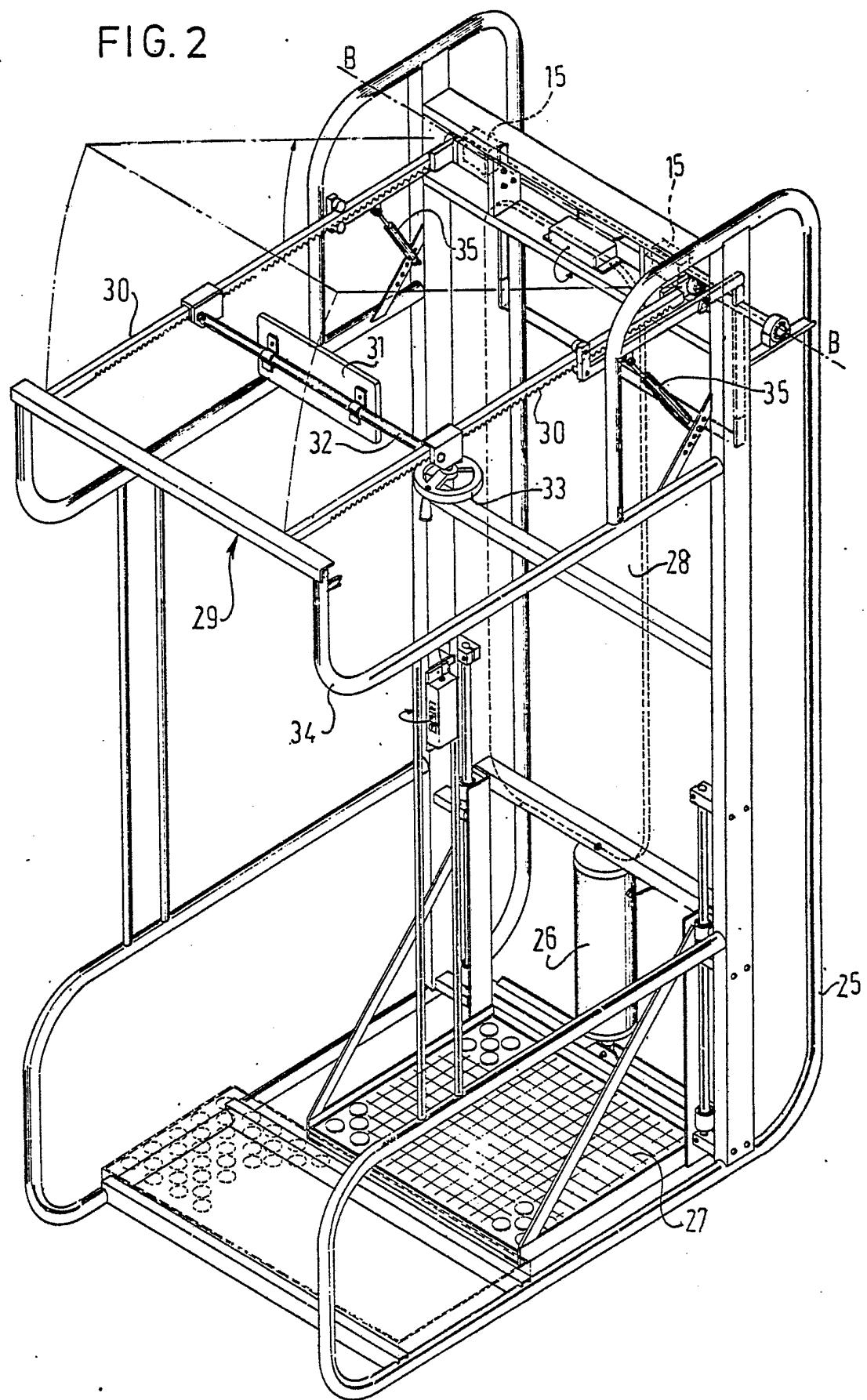




8203228

"2/2"

FIG. 2



8203228



US006159168A

United States Patent

[19]

Warner et al.

[11] **Patent Number:** **6,159,168**[45] **Date of Patent:** **Dec. 12, 2000**[54] **METHOD AND APPARATUS FOR INDUCING AND DETECTING ANATOMIC TORSION**[75] Inventors: **Michael John Warner**, Johnstown, Pa.; **James Allan Mertz**, Bricktown, N.J.[73] Assignee: **Cambria Medical Science, Inc.**, Johnstown, Pa.[21] Appl. No.: **09/117,821**[22] PCT Filed: **Feb. 7, 1997**[86] PCT No.: **PCT/US97/01399**§ 371 Date: **Jan. 28, 1999**§ 102(e) Date: **Jan. 28, 1999**[87] PCT Pub. No.: **WO97/28740**PCT Pub. Date: **Aug. 14, 1997****Related U.S. Application Data**

[60] Provisional application No. 60/011,405, Feb. 9, 1996.

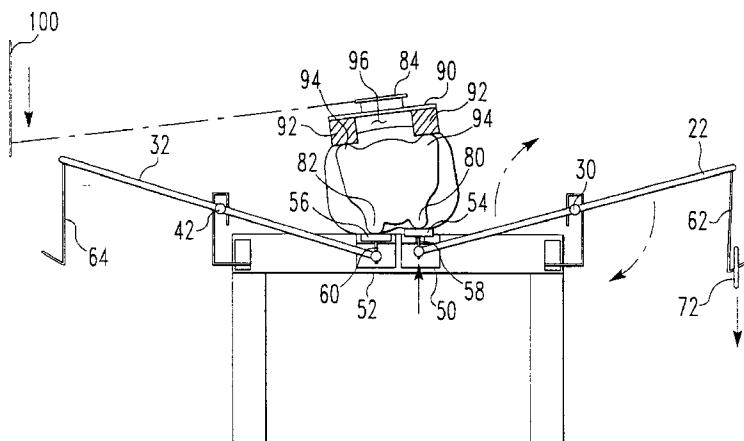
[51] Int. Cl.⁷ **A61B 5/103**[52] U.S. Cl. **600/594**[58] Field of Search 600/587, 594,
600/595[56] **References Cited****U.S. PATENT DOCUMENTS**

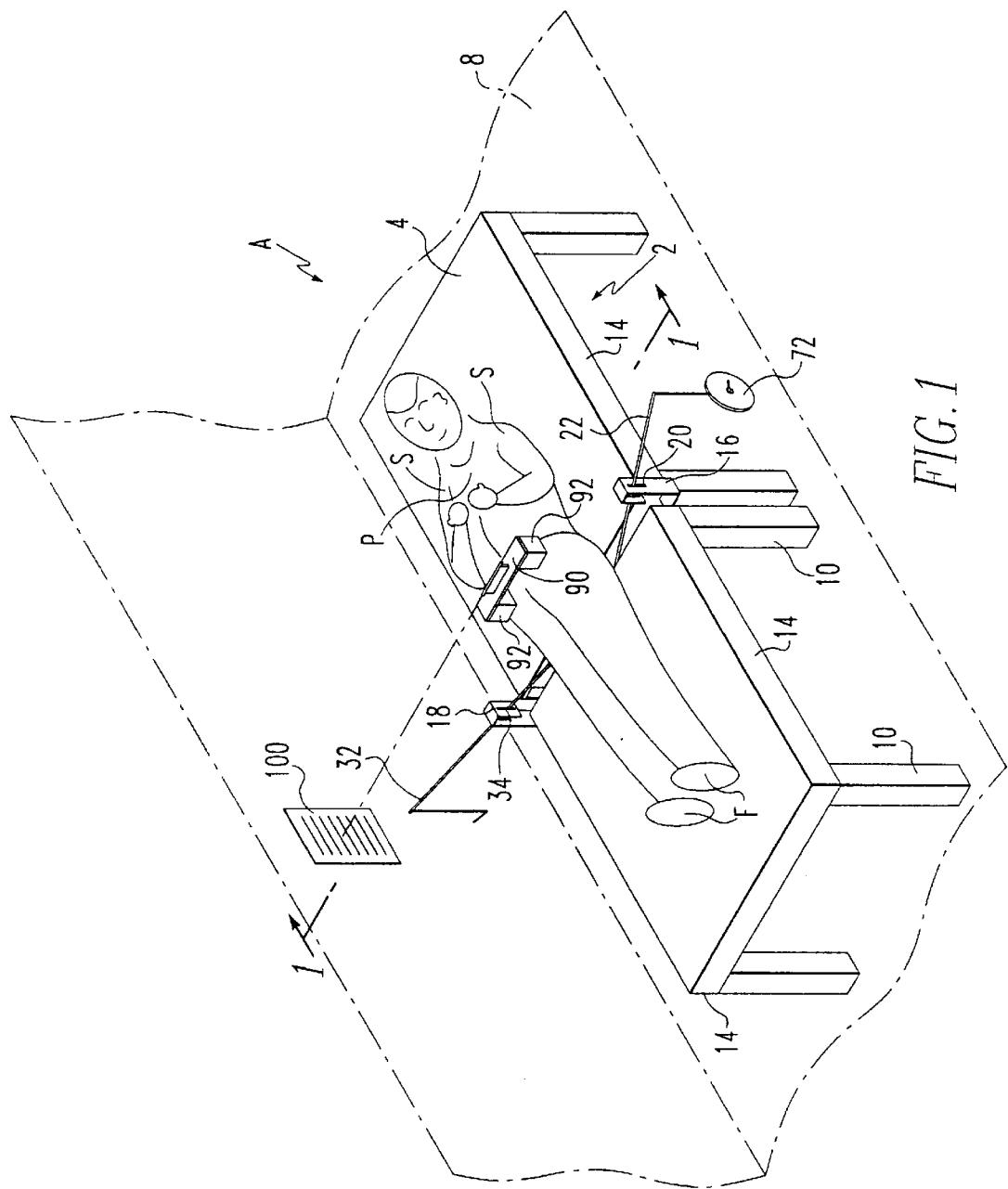
4,217,912	8/1980	Hubmann et al.	128/774
4,235,243	11/1980	Saha	128/740
4,250,894	2/1981	Frei et al.	128/774
4,297,884	11/1981	Leveque et al.	73/579
4,326,416	4/1982	Fredberg	73/597
4,416,269	11/1983	Enomoto et al.	128/41
4,649,934	3/1987	Fraser et al.	128/782
4,655,227	4/1987	Gracovetsky	128/781
4,664,130	5/1987	Gracovetsky	128/781
4,699,156	10/1987	Gracovetsky	128/781
4,754,763	7/1988	Doemland	128/739
4,799,498	1/1989	Collier	128/774
4,819,753	4/1989	Higo et al.	128/773
4,836,215	6/1989	Lee	128/714
4,844,085	7/1989	Gattinoni	128/720
4,858,126	8/1989	Croce, Jr.	364/413.02

4,969,471	11/1990	Daniel et al.	128/774
5,050,618	9/1991	Larsen	128/774
5,054,502	10/1991	Courage	128/774
5,058,600	10/1991	Schechter et al.	128/716
5,060,326	10/1991	Oswald	5/236.1
5,094,249	3/1992	Marras et al.	128/781
5,099,848	3/1992	Parker et al.	128/661.07
5,140,994	8/1992	Campbell et al.	128/782
5,179,940	1/1993	Barreiro	128/33
5,188,121	2/1993	Hanson	128/781
5,239,997	8/1993	Guarino et al.	128/630
5,337,758	8/1994	Moore et al.	128/781
5,373,858	12/1994	Rose et al.	128/782
5,398,697	3/1995	Spielman	128/781
5,400,800	3/1995	Jain et al.	128/782
5,402,781	4/1995	Dimarogonas	128/653.1
5,443,079	8/1995	Greenawalt	128/781
5,474,086	12/1995	McCormick et al.	128/782
5,573,012	11/1996	McEwan	128/782
5,588,444	12/1996	Petragallo	128/782
5,647,375	7/1997	Farfan de los Godos	600/594

Primary Examiner—Cary O'Connor*Assistant Examiner*—Pamela Wingood*Attorney, Agent, or Firm*—Webb Ziesenhein Logsdon Orkin & Hanson, P.C.[57] **ABSTRACT**

An anatomic torsion monitor includes an examination table (A) equipped with forcibly extendable pads (54, 56) which are utilized to rotationally displace a patient (P) about the patient's transverse axis. A laser (84), or other such pointer, is disposed on a platform (90) which rests across the abdomen of the patient (P) to measure the rotational displacement. The output of the laser (84) is projected onto a scaled chart (100). Clockwise and counterclockwise rotational displacements of the patient (P) as a function of applied forces are obtained by reading the projection of the laser (84) on the scaled chart (100) as the forces are applied and withdrawn. Plotting the rotational displacement versus force on a Cartesian coordinate system produces a continuous, bounded, four quadrant hysteresis loop (116). The data obtained and the hysteresis loop (116) produced therefrom provide a quantitative measure of the motion quality and the motion quantity of the lower back and is subject to detail analytic and medical application.

20 Claims, 4 Drawing Sheets



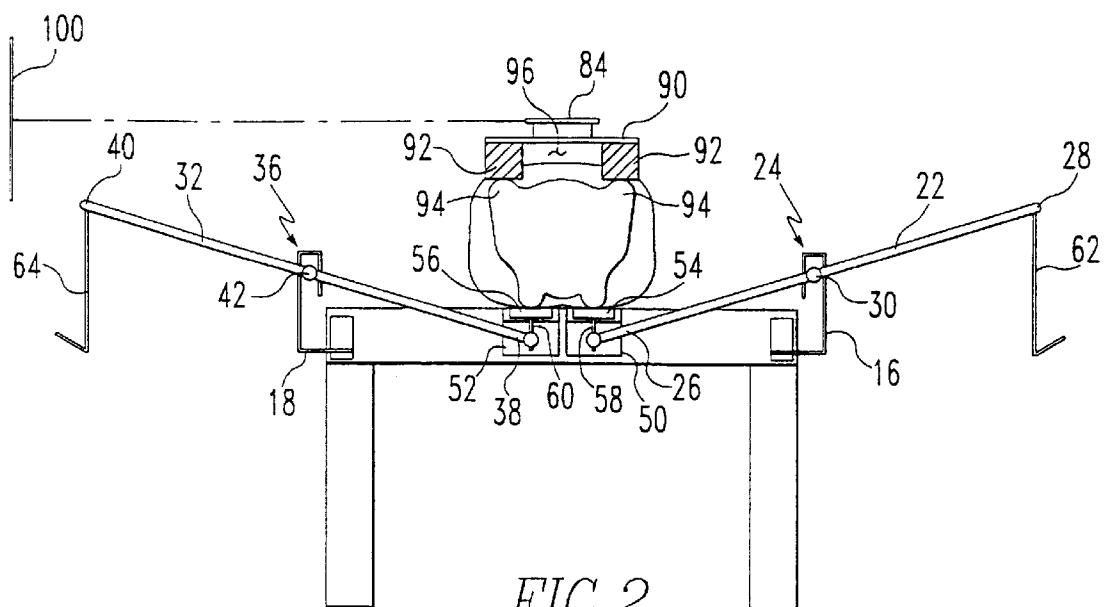


FIG. 2

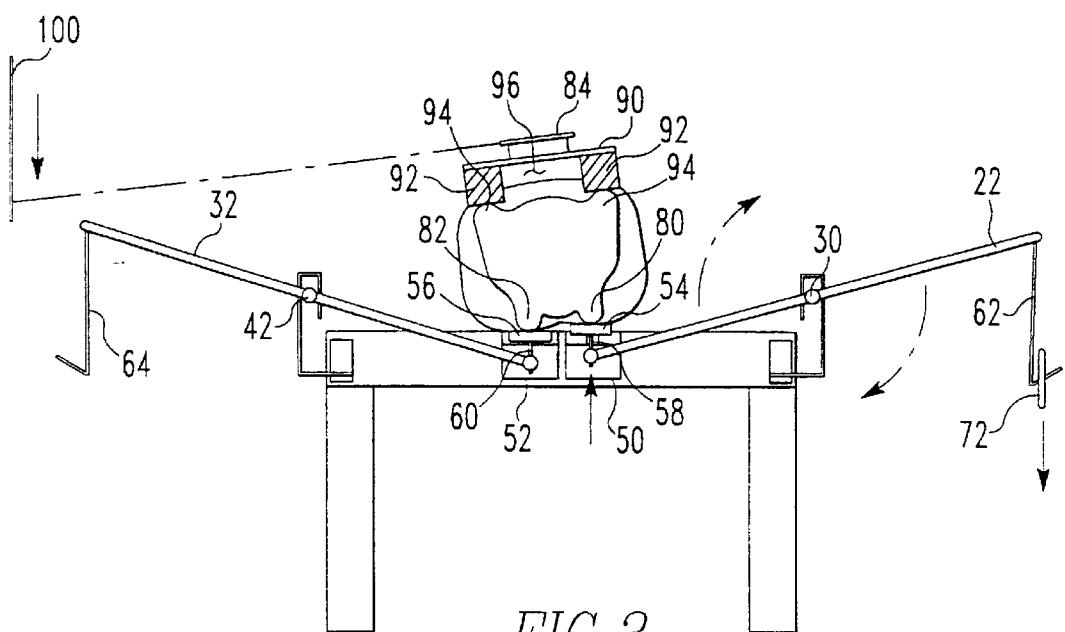


FIG. 3

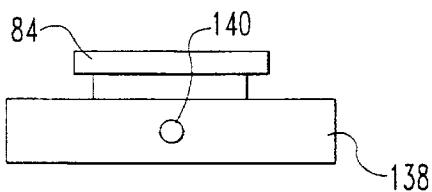


FIG. 8B

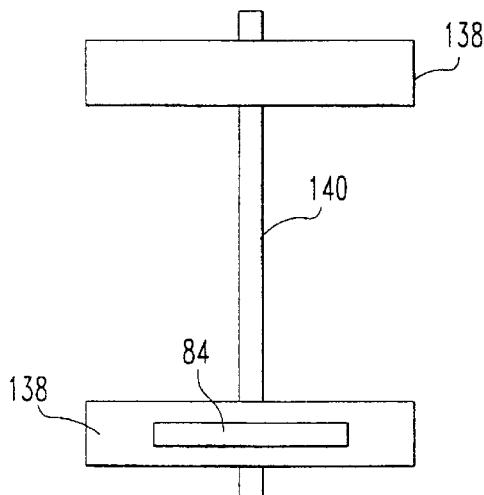


FIG. 8A

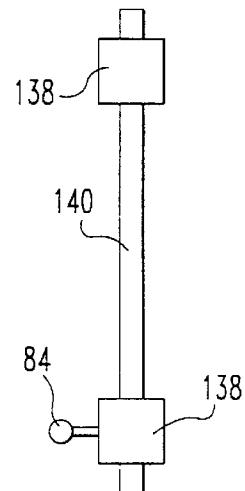


FIG. 8C

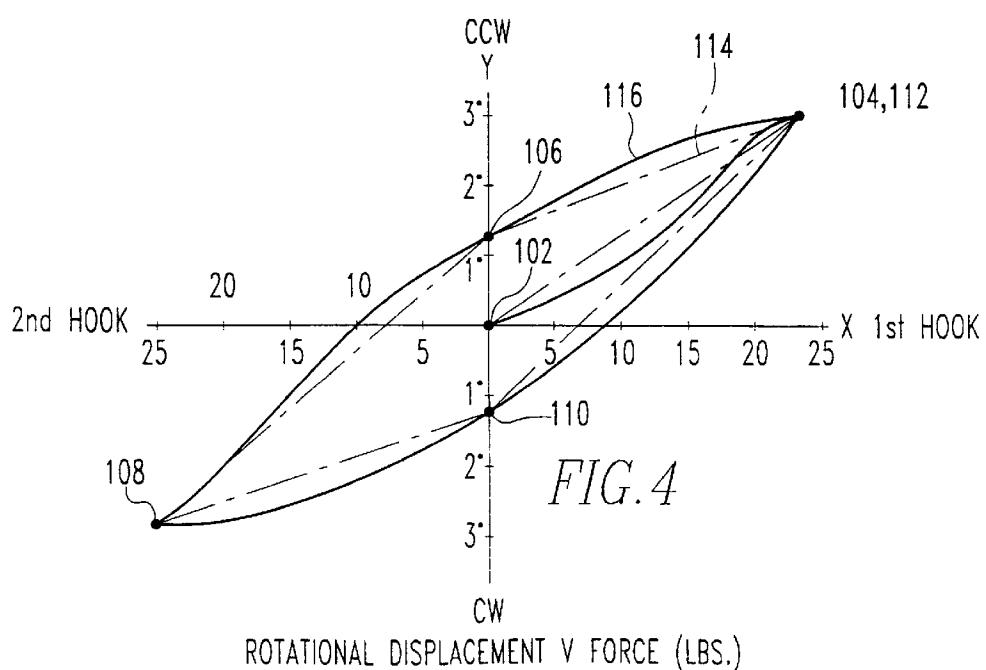
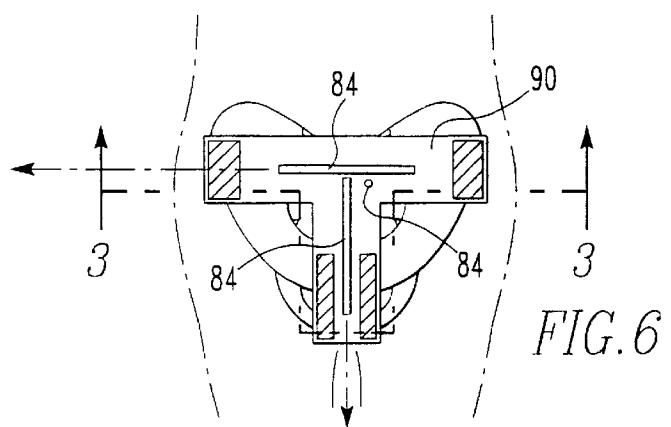
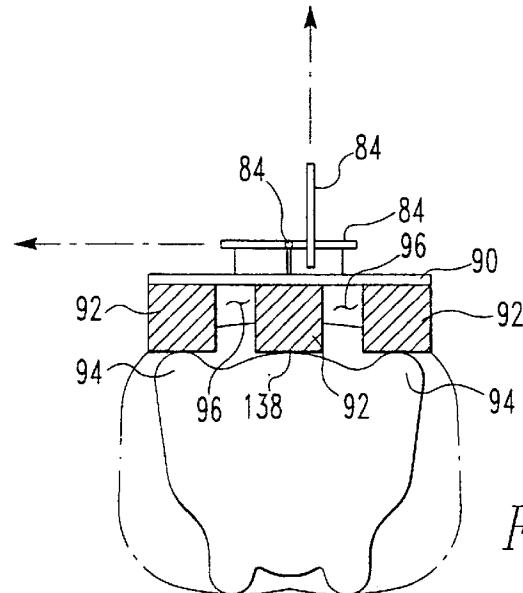
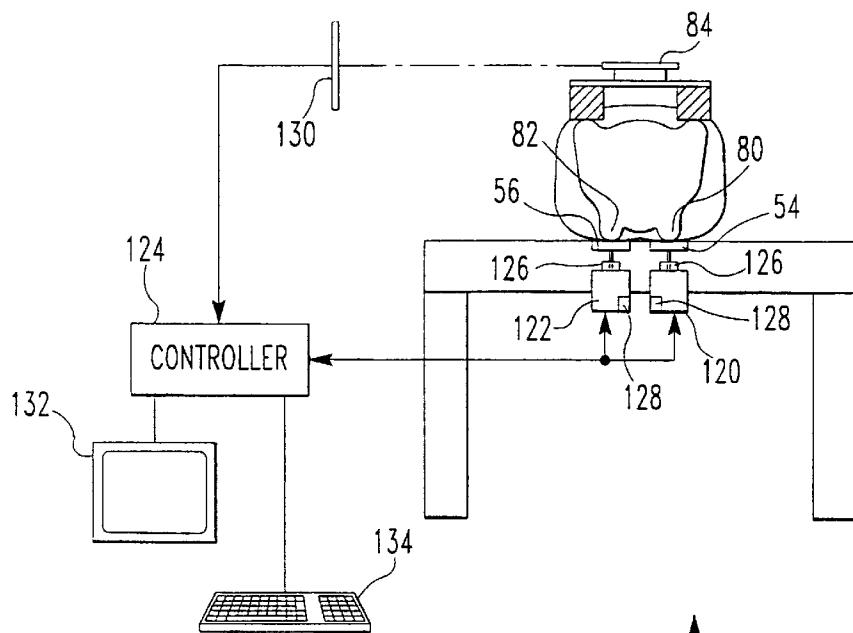


FIG. 4



1**METHOD AND APPARATUS FOR INDUCING
AND DETECTING ANATOMIC TORSION**

This application claims the benefit of Provisional application Ser. No. 60/011,405 filed Feb. 9, 1996.

1. FIELD OF THE INVENTION

This invention relates to orthopedic tables and, more particularly, to an anatomic torsion monitor for detecting myofascial musculoskeletal elasticity.

2. DESCRIPTION OF THE PRIOR ART

It is well known that the human low back is highly susceptible to dysfunction. Some estimates indicate that as much as 20 percent of the population at any one time experiences lower back pain. The annual cost in the United States of this common physical complaint in terms of lost or reduced productivity, and medical costs, is estimated at \$100 Billion U.S. dollars yearly. Moreover, low back medical care is typified as having the least return to society for the effort and resources expended.

A common technique utilized by physicians to evaluate low back dysfunction is a pelvic roll. In this technique, the physician's fingers contact the Posterior Superior Iliac Spines (PSIS) of a passive supine patient. An anteriorly directed force applied to one side of the PSIS produces a rotational torque on the lower back. The physician detecting how the PSIS lifts in relation to how much force is applied provides a relative indication of the ability of the lower back to rotate. Normal patients roll with ease from side to side. However, patients with low back dysfunctions roll with less than equal symmetry. Those with moderate to severe dysfunctions roll in one direction with ease while roll in the other direction is met with an abrupt and forceful restriction barrier. Occasionally, the pelvis rolls poorly in both directions. The pelvic roll is a reliable test of low back function since the patient is passive, supine and resting quietly which eliminates the contraction of weight bearing muscles.

The motion of the lumbar vertebrate during the pelvic roll is of particular interest because of facet orientation. Specifically, the bony architecture of the lumbar vertebrate have intervertebral facets closely oriented to the sagittal plane. These facets function to direct and steer the discs. Movement in the sagittal and coronal planes is well tolerated, while rotation in the transverse plane is extremely limited. Clinically, rotation in the transverse plane is a very sensitive indicator of motion function and dysfunction because of its very narrow range of motion arc.

The pelvic roll and other diagnostic techniques for low back problems are subjectively used by physicians in clinical practice. The difficulty in treating patients with low back problems often lies in the inability to make an objective analysis. For example, health care providers who practice manual manipulative medicine, claim to have the ability to make musculoskeletal assessment based on factors of quantity and quality. These practitioners are able to palpitate the body and formulate treatment based entirely on the diagnosis obtained by palpitation. Treatment may include manipulation, physical therapy, medicine, surgery or continued observation.

Of particular interest is the assessment of motion quality in terms of tissue response. This is more than a degree of range of motion. Tissue response is how the body reacts to energy transfer. It is the result of a given force supplied, maintained and withdrawn. Terms such as ease of motion and stiffness have been used to describe this dimension of palpitory diagnosis.

2

Studies have been conducted to define and quantify elasticity, stiffness and motion quality of the human body. These studies, however, have not been able to correlate the mechanical and clinical concepts of elasticity, stiffness and motion quality.

It is therefore an object of the present invention to provide an anatomic torsion monitor that can provide a quantitative measurement of the myofascial-musculoskeletal elasticity. It is an object of the present invention to provide a method for detecting elasticity of muscles, ligaments and myofascial structure in a patient.

SUMMARY OF THE INVENTION

Accordingly, we have invented an anatomic torsion apparatus which includes an examination table for positioning a patient so that the muscles associated with a portion of the anatomy of the patient are relaxed; a rotational torque means which applies a rotational torque to the portion of the anatomy in a first direction and a rotational torque in a second direction opposite the first direction; a rotation displacement measuring means which measures rotational displacement of the anatomy in response to the application or removal of the rotational torque in the first direction and the application removal of the rotational torque in the second direction.

The rotational torque means includes a first pad and a second pad. Each pad is forcibly extendable transverse to a plane of the examination table. The first pad and the second pad are individually extendable. The first pad and the second pad are substantially coplanar with the patient receiving side of the examination table when contracted. The first pad and the second pad are positionable to contact the posterior superior iliac spines of a patient. The forcible extension of the first pad causes rotation of the transverse axis of the patient. The rotation displacement measuring means includes at least one pointer, preferably a laser, positionable to rotate with the anatomy. A detector is positioned to detect the rotational displacement of the pointer as a function of the movement of the projection of the beam of light output by the laser on the detector during rotation of the anatomy.

In one embodiment, the rotational torque means includes a lever attached to each pad. Each lever has a first end attached to a side of the pad opposite the patient receiving side of the examination table. The lever is pivotable about a point between the first end and the second end of the lever. In another embodiment, the rotational torque means includes a linear electric motor, an electric motor and cam arrangement or a hydraulic arrangement for forcibly extending the pad into the patient. The pad, preferably, includes a gimbal ring positioned on the side thereof opposite the patient side. The gimbal ring enables the pad to pivot with respect to the surface of the examination table when the pad is forcibly extended therefrom.

In another embodiment, a method of detecting elasticity of muscles in a patient is provided. In the method, a first force is applied to the patient to cause rotation about the transverse axis of the patient in a first direction. The rotational displacement of the patient about the transverse axis is recorded as a function of the applied first force. The first force is removed and the rotational displacement of the patient in the absence of an applied force is measured. A second force is applied to the patient to cause rotation about the transverse axis of the patient in a second direction opposite the first direction. The rotational displacement of the patient about the transverse axis is recorded as a function of the applied second force. The second force is removed

3

and the rotational displacement of the patient in the absence of applied force is measured.

The method may further include incremental or continuous measurement of the rotational displacement as a function of the application and removal of the first force and the measurement of the rotational displacement as a function of the application and removal of the second force. Moreover, the rotation displacement of the patient in the first direction and the second direction can be determined as a function of time. The rotational displacement of the patient in the first direction and the second direction as a function of time can be Fourier transformed to obtain a spectral analysis thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an anatomical torsion apparatus with a supine patient disposed thereon;

FIG. 2 is a cross section of the apparatus and patient of FIG. 1 taken along section lines 1—1;

FIG. 3 is the apparatus and patient of FIG. 2 illustrating the lower back of the patient undergoing rotational torque;

FIG. 4 is a Cartesian coordinate plot of rotational displacement of the lower back of the patient in response to the application of force thereto;

FIG. 5 is a cross section of another embodiment of the anatomic torsion apparatus;

FIG. 6 is an embodiment of a platform for supporting a plurality of lasers that are utilized to detect the rotational displacement of the lower back of the patient in a plurality of orthogonal planes;

FIG. 7 is a cross section of the platform and patient of FIG. 6 taken across section lines 3—3; and

FIGS. 8a-8c are top, front and side views of a calibration standard utilized to calibrate the anatomic torsion monitor of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, an examination or treatment table A has a substantially planar top 2 having a patient receiving side 4 adapted to receive a patient or subject P to be examined thereon. The top 2 of the examination table 4 is held in spaced relation to a floor 8 by a plurality of legs 10 extending between the floor 8 and a side of the top 2 opposite the patient receiving side 4. The examination table A has a lateral slot 12 formed therein that preferably extends between the sides 14 of the table. A first pivot bracket 16 extends across the slot 12 at one end thereof and a second pivot bracket 18 extends across the slot at the other end thereof. Alternatively, the examination table A is formed from two tables positioned end-to-end and secured together by the first pivot bracket 16 and the second pivot bracket 18 extending between the tables.

With reference to FIG. 2 and with continuing reference to FIG. 1, the first pivot bracket 16 has an aperture 20 formed therein which is adapted to receive a first lever 22. A central part 24 of the first lever, between a first end 26 and a second end 28 thereof, is joined to the first pivot bracket 16 by a first pivot bearing 30 which forms a pivot for the first lever 22. A second lever 32 is received in an aperture 34 formed in the second pivot bracket 18 in a manner similar to the first lever 22 received in the aperture 20 of the first pivot bracket 16. A central part 36 of the second lever 32, between a first end 38 and second end 40 thereof, is joined to the second pivot bracket 18 by a second pivot bearing 42 which forms a pivot for the second lever 32. Preferably, the first pivot bearing 30

4

and the second pivot bearing 42 are positioned symmetrically on opposite sides of the longitudinal axis of the examination table A and at the same level relative to the patient receiving side 4 of the examination table A.

The first pivot bracket 16 and the second pivot bracket 18 are positioned so that the levers 22, 32 are oriented transverse, and preferably orthogonal, to the longitudinal axis of the examination table A. The first end 26, 38 of each lever 22, 32 is positioned to move vertically through the slot and the second end 28, 40 of each lever 22, 32 extends outward from the sides 14 of the examination table A. Moving the second end 28, 40 of each lever 22, 32 upwardly pivots the lever 22, 32 on its pivot bearing 30, 42 thereby causing the first end 26, 38 thereof to move downwardly. Similarly, moving the second end 28, 40 of each lever 22, 32 downwardly pivots the lever 22, 32 on its pivot bearing 30, 42 so that the first end 26, 38 thereof moves upwardly.

A first support bracket 50 and a second support bracket 52 are positioned in the slot 12. The first support bracket 50 and the second support bracket 52 are adapted to support a first pad 54 and a second pad 56, respectively. The first pad 54 and second pad 56 are supported with their upper surfaces substantially coplanar with the patient receiving side 4 of the examination table A. The first pad 54 and the second pad 56 have a first shaft 58 and a second shaft 60, respectively, extending from lower sides thereof and in a direction opposite the receiving side 4 of the examination table A. The first support bracket 50 and the second support bracket 52 are positionable in the slot 12 to enable the first pad 54 and the second pad 56 to be located at desired locations in the slot, to be described in greater detail hereinafter. When the first pad 54 and the second pad 56 are positioned at the desired locations in the slot 12, e.g., symmetrical with the longitudinal axis of the examination table A, the first support bracket 50 and the second support bracket 52 are fixed in position in the slot 12.

The first shaft 58 is slidably received in the first support bracket 50 so that an upwardly directed force applied to an end of the first shaft 58 opposite the first pad 54 causes the first pad 54 to be forcibly extended transverse to the patient receiving side 4 of the examination table A. Similarly, the second shaft 60 is slidably received in the second support bracket 52 so that an upwardly directed force applied to an end of the second shaft 60 opposite the second pad 56 causes the second pad 56 to be forcibly extended transverse to the patient receiving side 4 of the examination table A. The first pad 54 and the second pad 56 are forcibly extendable transverse to the patient receiving side 4 of the examination table A, preferably, in a plane that extends between the ends of the slot 12 and generally orthogonal to the patient receiving side 4 of the examination table A. When forcibly extended, each pad 54, 56, preferably, converges towards the longitudinal axis of the examination table A at an angle, preferably, between 67 degrees and 69 degrees relative to the patient receiving side 4 of the examination table A. However, other angles of convergence or forcible extension normal to the patient receiving side 4 of the examination table A may also be utilized. The phrase "upwardly directed force" shall be utilized herein to describe the direction of the force applied lengthwise to the shafts 58, 60 which cause the forcible extension of the pads 54, 56.

The first end 26 of the first lever 22 is connected to the end of the first shaft 58 opposite the first pad 54 and the first end 38 of the second lever 32 is connected to the end of the second shaft 60 opposite the second pad 56. The length of the first lever 22 and the length of the second lever 32 are selected so that applying a known downwardly directed

5

force at the second end 28 of the first lever 22 or the second end 40 of the second lever 32 produces a desired upwardly directed force at the corresponding first end 26, 38. The upwardly directed force at the first end 26 of the first lever 22 or the first end 38 of the second lever 32 imparts an upwardly directed driving force to the corresponding first shaft 58 or second shaft 60 which cause the respective first pad 54 or second pad 56 to be forcibly extended transverse to the patient receiving side 4 of the examination table A.

To enable the application of known downwardly directed forces on the levers 22, 32, a first L-shaped hook 62 is connected at its upper end to the second end 28 of the first lever 22 and a second L-shaped hook 64 is connected at its upper end to the second end 40 of the second lever 32. The ends of the hooks 62, 64 opposite the levers 22, 32 are preferably adapted to receive a conventional exercise plate 72. To maintain the exercise plate 72 received on the hooks, the ends of the hooks 62, 64 opposite the levers 22, 32 are preferably tapered upwardly.

With reference to FIG. 3 and with continuing reference to all previous Figs., the first pad 54 and first shaft 58 cause the first lever 22 to experience a force acting to rotate the first lever 22 about the first pivot bearing 30 in a first, counterclockwise, direction. This counterclockwise force is of sufficient extent, in the absence of an exercise plate 72 disposed on the first hook 62, to maintain the first lever 22 in a start position, shown in FIG. 2. Similarly, the second pad 56 and the second shaft 60 cause the second lever 32 to experience a force acting to rotate the second lever 32 in a second, clockwise, direction about the second pivot bearing 42. This clockwise force is of sufficient extent, in the absence of an exercise plate 72 disposed on the second hook 64, to maintain the second lever 32 in a start position. In the start positions, the upper surface of the first pad 54 and the upper surface of the second pad 56 are substantially coplanar with the patient receiving side 4 of the examination table A.

Applying one or more exercise plates 72 to, for example, the first hook 62 causes the first lever 22 to experience a force acting to rotate the first lever in the second, clockwise, direction about the first pivot bearing 30. In response to this clockwise rotation force, the first shaft 58 experiences an upwardly directed force that acts to forcibly extend the first pad 54 transverse to the patient receiving side 4 of the examination table A. Removal of the one or more exercise plates 72 causes the first lever 22 to experience a counterclockwise force acting to return the first lever 22 to its start position. The second lever is similarly rotatable in the counterclockwise and clockwise direction about the second pivot bearing 42 by the respective addition and removal of one or more exercise plates 72 to the second hook 64.

With continuing reference to FIG. 3, the subject or patient P reclines on the examination table A in a supine position. The patient P is positioned on the examination table A so that the Left-Posterior-Superior-Iliac-Spine (LPSIS) 80 and Right-Posterior-Superior-Iliac-Spine (RPSIS) 82 of the patient P are positioned in or above the slot 12. The patient P is preferably positioned on the examination table A so that the sagittal plane of the patient extends parallel with and through the longitudinal axis of the examination table A. The position of the first support bracket 50 and the second support bracket 52 are adjusted in the slot 12 so that the first pad 54 is aligned with, for example, the LPSIS 80 and the second pad 56 is aligned with the RPSIS 82. Reversal of the head and feet position of the patient P on the examination table A will reverse which one of the Posterior-Superior-Iliac-Spine (PSIS) of the patient P, i.e., the LPSIS 80 or the RPSIS 82, is aligned with the first pad 54 and the second pad 56.

6

As shown in FIG. 3, placement of one or more exercise plates 72 on the first hook 62 causes the first lever 22 to impart an upwardly directed force on the first shaft 58. In response to the upwardly directed force on the first shaft 58, the first pad 54 is forcibly extended into contact with the LPSIS 80 of the patient. The forcible extension of the first pad 54 into the LPSIS 80 of the patient P urges the patient P to rotate about the transverse axis of the patient P in a first, counterclockwise, direction, preferably about the patient's RPSIS 82. During the procedure, the patient P, preferably, rests comfortably and passively on the examination table A and the shoulders S and feet F of the patient remain on the patient receiving side 4 of the examination table A during rotation about the transverse axis of the patient P. Thus, forcible extension of the first pad 54 into the LPSIS 80 of the patient produces a rotational torque on the spine of the patient P in the counterclockwise direction. Similarly, placement of one or more exercise plates 72 on the second hook 64 causes the second lever 32 to impart an upwardly directed force to the second shaft 60 which causes the second pad 56 to be forcibly extended into contact with the RPSIS 82 of the patient P. The second pad 56 forcibly contacting the RPSIS 82 of the patient P produces a rotational torque on the spine of the patient P in the clockwise direction, preferably about the patient's LPSIS 80. Preferably, exercise plates 72 are applied to the first hook 62 independent of the exercise plates being placed on the second hook 64, and vice versa.

To measure the rotational displacement of the spine of the patient P in response to the produced rotational torque, a pointer 84, such as a laser, is positioned adjacent the patient's abdomen in a manner to rotate with the spine of the patient P. The laser 84 produces a output beam of highly focused light that is, preferably, projected orthogonal to the sagittal plane of the patient P.

To ensure the laser 84 rotates with the anatomy being measured, i.e., spine, the laser 84 is secured to a platform 90 which is secured to the patient P. A standoff 92 is disposed on opposite ends of the platform 90 on the side thereof opposite the laser 84. In use, the standoffs 92 are positioned to contact the Anterior-Superior-Iliac Spines (ASIS) 94 of the patient P and the platform 90 is suspended above the patient P between the standoffs 92 thereby forming a gap 96 between the platform and the patient. To ensure the standoffs 92 remain positioned on the ASIS 86 of the patient P, the platform 90 and standoffs 92 are secured to the patient P via, for example, a belt (not shown) surrounding the patient P and the platform 90.

A scaled chart 100 is positioned to receive the beam of light output by the laser 84. The scales on the scaled chart 100 are calibrated so that the projection of the laser 84 on the scaled chart 100 moves thereon in response to rotation of the spine of the patient P by the forcibly extension of the first pad 54 and second pad 56 into the patient P. The movement of the projection of the laser 84 on the scaled chart 100 provides an indication of the rotational displacement of the spine of the patient P.

With reference to FIG. 4 and with continuing reference to all previous Figs., in use, the patient P is positioned on the patient receiving side 4 of the examination table A. The LPSIS 80 and RPSIS 82 of the patient P are positioned on the first pad 54 and second pad 56 and the standoffs 92 of the platform 90 supporting the laser 84 are positioned and secured on the ASIS 86 of the patient P. A first reading 102 of the projection of the laser 84 on the chart is recorded in the absence of an exercise plate 72 placed on either the first hook 62 or the second hook 64. This first reading is the "zero" or reference reading. An exercise plate 72 of desired

mass is then placed on the first hook 62. In response to the placement of the exercise plate 72 on the first hook 62, the first pad 54 is forcibly extended. This forcible extension of the first pad 54 causes the patient P, and specifically the LPSIS 80 of the patient P, to rotate counterclockwise thereby causing the projection of the laser beam on the scaled chart 100 to move downward. Once the rotation of the patient P stabilizes, the weight of the exercise plate 72 and a second reading 104 of the position of the projection of the laser beam on the scaled chart 100 are recorded. The exercise plate 72 is then removed from the first hook 62. A third reading 106 of the rotational displacement of the patient P is recorded in the absence of an exercise plate 72 on either of the first hook 62 or second hook 64. As shown in FIG. 4, the third reading 106 indicates that the rotational displacement of the patient P after removing the exercise plate 72 from the first hook 62 does not return to the first, zero or reference, reading 102 obtained prior to the application of rotating torque to the patient's P spine. It is believed that this offset between the first reading 102 and the third reading 106 is caused by the lower back, and specifically the patient's lumbar spine, sacroiliac joints and myofascial structures of the lower back, retaining part of the energy introduced by the forcible extension of the first pad 54 into the LPSIS 80 of the patient P.

The exercise plate 72 is next placed on the second hook 64. In response to the placement of the exercise plate 72 on the second hook 64, the second pad 56 is forcibly extended into the RPSIS 82 of the patient P. The forcible extension of the second pad 56 causes the patient P to rotate clockwise thereby causing the projection of the laser beam on the scaled chart 100 to move upward. Once the rotation of the patient stabilizes, the weight of the exercise plate 72 and a fourth reading 108 of the position of the projection of the laser on the scaled chart 100 are recorded. The exercise plate 72 is then removed from the second hook 64 and a fifth reading 110 of the rotational displacement of the patient P in the absence of the exercise plate 72 are recorded. As shown in FIG. 4, the fifth reading 110 indicates that the rotational displacement of the patient after removing the exercise plate from the second hook 64 does not return to the zero reference obtained at the first reading 102 nor does it return to the value of the third reading 106. It is believed that this offset is caused by the lower back retaining part of the energy introduced by the forcible extension of the second pad 56 into the RPSIS 82. The exercise plate 72 is again placed on the first hook 62, which causes the first pad 54 to be forcibly extended. The forcible extension of the first pad 54 causes the patient P to rotate counterclockwise thereby causing the projection of the laser on the scaled chart 100 to move downward. Once the rotation of the patient P stabilizes, the weight of the exercise plate 72 and a sixth reading 112 of the position of the laser on the chart are recorded. The value of the sixth reading 112 is the same or near the value of the second reading 104.

Plotting on a Cartesian coordinate system, the first reading 102 through the sixth reading 112 as a function of the weight of the exercise plate 72, and sequentially joining the first reading 102 through sixth reading 112 with a dashed line results in a first hysteresis loop 114. Plural measurement of the rotational displacement of the spine of the patient P in the counterclockwise and clockwise direction reveals that the rotational displacement as a function of applied weight substantially follows the first hysteresis loop 114.

To obtain a more detailed plot, additional measurements of the rotational displacement of the spine of the patient P as a function of the addition and removal of exercise plates 72

to the first hook 62 and second hook 64 are recorded. For example, the first zero or reference, reading 102 is recorded in the absence of an exercise plate 72 on the hooks 62, 64. An exercise plate 72 weighing, for example, five pounds is placed on the first hook 62. The total weight of the exercise plates 72 on the first hook 62, i.e., five pounds, and the counterclockwise rotational displacement of the spine of the patient P in response thereto are recorded. An additional five pound exercise plate 72 is placed on the first hook 62. The total weight of the exercise plates 72 on the first hook 62, i.e., ten pounds, and the counterclockwise rotational displacement of the spine of the patient P in response thereto are recorded. Additional five pound exercise plates 72 are incrementally placed on the first hook 62. The total weight and counterclockwise rotational displacement of the patient's P spine in response to the incremental addition of each exercise plate 72 are recorded up to a maximum desired weight, e.g., twenty-five pounds, on the first hook 62. The five pound exercise plates 72 then are incrementally removed from the first hook 62 and the total remaining weight and the rotational displacement of the spine of the patient P after removing each exercise plate 72 are recorded. After the last plate 72 has been removed from the first hook 62, the residual counterclockwise rotational displacement of the spine of the patient P is recorded. A five pound exercise plate 72 is then placed on the second hook 64 and the total weight of the exercise plates 72 on the second hook 64, i.e., five pounds, and the clockwise rotational displacement of the spine of the patient P in response thereto are recorded. Another five pound exercise plate 72 is placed on the second hook 64 and the total weight, i.e., ten pounds, and the clockwise rotational displacement of the spine of the patient P in response thereto are recorded. Additional five pound exercise plates 72 are incrementally placed on the second hook 64. The total weight and the clockwise rotational displacement of the spine of the patient P in response to the incremental addition of each exercise plate 72 are recorded up to the maximum desired weight. The five pound exercise plates 72 are then incrementally removed from the second hook 64 and the total remaining weight after removing each exercise plate 72 and the clockwise rotational displacement of the patient P in response thereto are recorded. After the last exercise plate 72 is removed from the second hook 64, the residual clockwise rotational displacement of the spine of the patient P is recorded. The incremental placement of five pound exercise plates 72 on the first hook 62 and the recording of the total weight and the counterclockwise rotational displacement of the spine of the patient P for the incremental addition of each exercise plate 72 is repeated until the desired maximum weight has again been placed on the first hook 62. Thereafter, the exercise plates 72 are removed from the hooks 62, 64.

A plot is formed on a Cartesian coordinate system of the rotational displacements of the spine of the patient P as a function of the incremental total weight added and removed from the first hook 62 and the second hook 64. Specifically, the total weight on the first hook 62 is represented on the positive abscissa, the counterclockwise rotational displacement is represented on positive ordinate, the total weight on the second hook is represented on the negative abscissa and the clockwise rotational displacement is represented on the negative ordinate. For a patient P with a healthy lower back, the plot of rotational displacement versus total weight results in a second hysteresis loop 116.

The actual shape of the hysteresis loops 114, 116 for healthy lower backs may vary from patient to patient. However, the general shape of these hysteresis loops 114,

116 will be similar. For patient's with unhealthy lower backs, the hysteresis loops 114, 116 will be perceptibly distorted in one or more quadrants of the Cartesian coordinate system. Moreover, as a patient P recovers from a lower back injury, the hysteresis loops will transition from a distorted hysteresis loop toward, for example, the second hysteresis loop 116.

With reference to FIG. 5, a first drive 120 and a second drive 122, such as a first and second motor/cam arrangement, a first and second first linear motor or a first and second hydraulic arrangement, are utilized to controllably impart an upwardly directed force to the first pad 54 and the second pad 56, respectively. Specifically, a controller 124 outputs to the first drive 120 and the second drive 122 individual control and/or drive signals. In response to receiving the control signals, each drive 120, 122 imparts to its corresponding pad 54, 56 an upwardly extending force corresponding to the received control signals. By adjusting the control signals to each drive 120, 122, the extent of the upwardly extending force imparted to each pad 54, 56 can be controlled. To accurately measure the extent of the applied upwardly extending force, each drive 120, 122; pad 54, 56 or shaft 58, 60 may be equipped with a corresponding force sensor 126, such as a load cell, which converts the upwardly extending force of the pad coating with the spine of the patient P into an electrical signal detectable by the controller 124. The controller 124 utilizes the electrical signal output by the force sensors 126 in a feedback mode to determine if the applied control signal is causing the corresponding drive 120, 122 to produce the desired extent of upwardly extending force. The controller 124 also utilizes the electrical signals output by the force sensors 126 to detect if insufficient force is being detected, as would occur if the patient P shifts off a pad 54, 56. Each drive 120, 122 each may also include a position detector 128, such as an encoder or a resolver, which detects the distance the pad 54, 56 has traveled from the patient receiving side 4 of the examination table A. The position detectors 128 can be utilized, without limitation, to limit the extent of travel of the pads 54, 56. The position detectors 128 can also be utilized to obtain an indication of the rotational displacement of the patient P.

An optical array 130, formed from a plurality of optical pick-ups, such as photo-diodes, is positioned in the projected light path output by the laser 84. Each optical pick-up is adapted to produce an electrically detectable signal in response to the receipt of light from the laser 84. The optical array 130 is positioned in the path of light output by the laser 84 and is adapted to detect and provide an indication of the position of light from the laser 84 impinging thereon. The optical array 130 is suitably placed relative to the laser 84 to enable accurate detection of the movement of the projection of the beam of light from the laser 84 as a function of the rotational displacement of the patient P. The optical array 130 is connected to the controller 124 which includes suitable circuitry to enable the detection of which one, or ones, of the optical pick-ups in the optical array 130 are producing an electrically detectable signal in response to the receipt of light from the laser 84.

The controller 124, preferably, has a CRT 132 and a keyboard 134 attached thereto for enabling a operator to interface therewith. The controller 124 includes suitable operating software and hardware for controlling the operation of the drives 120, 122, the receipt electrically detectable signals from the optical array 130, the generation of images on the CRT 132 and the receipt of inputs from the keyboard 134.

In use, the controller 124 coordinates the operation of the drives 120, 122 and the optical array 130 to obtain readings of the rotational displacement of the spine of the patient P as a function of force applied to the LPSIS 80 and RPSIS 82. Specifically, once the PSIS of the patient P are positioned on the first pad 54 and second pad 56, the controller 124 samples the optical array 130 to determine which one, or ones, of the optical pick-ups is receiving light from the laser 84. The controller 124 increments the upwardly directed force applied to, for example, the LPSIS 80 of the patient P by the first drive 120 and detects the rotational displacement of the patient P in response thereto by sampling the optical array 130 after each increment of upwardly applied force. The upwardly directed force applied by the first drive 120 is in the absence of an upwardly directed force applied by the second drive 122. When the maximum desired upwardly directed force has been applied by the first drive 120, the controller 124 decrements the upwardly directed force and detects the return rotational displacement of the patient P by sampling the optical array 130 after each such decrement. The controller 124 then increments increases the upwardly applied force applied to the RPSIS 82 of the patient P by the second drive 122 and detects the rotational displacement of the spine of the patient P in response thereto by sampling the optical array 130 after each increment of upwardly applied force. The upwardly directed force applied by the second drive 122 is in the absence of an upwardly directed force being applied by the first drive 120. When the maximum desired upwardly directed force has been applied by the second drive 122, the controller 124 decrements the upwardly applied force and detects the return rotational displacement of the RPSIS 82 of the patient P by sampling the optical array 130 after each such decrement. The increment and decrement of upwardly applied force by the first drive 120 and the second drive 122 and the detection of the rotational displacement of the spine of the patient P in response thereto can continue until sufficient data regarding the rotational displacement as a function of the upwardly directed force has been accumulated.

The controller 124 preferably includes software to generate from the accumulated data, a hysteresis loop, e.g., the second hysteresis loop 116 in FIG. 4, for the patient P. This hysteresis loop can be displayed on the CRT 132 or printed on a printer (not shown). The controller 124 may also include suitable mass storage (not shown) for storing the data regarding the rotational displacement as a function of upwardly applied force for subsequent retrieval and analysis. Such analysis may include, without limitation, the generation of additional hysteresis loops or the Fourier Transforming of the data into the frequency domain for spectral analysis.

To enable the application of forces in a desired direction while the patient P is being rotated, each pad 54, 56 is preferably attached to a shaft 58, 60 via a gimbal ring 136. The gimbal rings 136 enable the pads 54, 56 to maintain a desired direction of force on the patient P during the forcible extension of the pads 54, 56.

Rotational displacement of the patient P three degrees clockwise and three degrees counterclockwise, for a total of six degrees, is believed to provide sufficient diagnostically useful information about the lower back. It is to be appreciated, however, that additional degrees of clockwise and counterclockwise rotational displacement can also be utilized.

With reference to FIGS. 6 and 7, the platform 90 is adapted to support two or more lasers 84 orthogonal to each other. Standoffs 92 are disposed on the side of the platform

11

90 opposite the lasers 84 and are positioned to contact the ASIS 94 and the pubic bone 138 of the patient P. The standoffs 92 are of sufficient height so that the platform 90 bridges the standoffs 90 and forms the gap 96 with the abdomen of the patient P. The standoffs 92 and platform 90, including lasers 84, are positioned on the patient P and secured to the patient utilizing, for example, a belt. The output of each laser 84 is projected onto a scaled chart 100 or an optical array 130. The rotational displacement of the spine of the patient P as a function of applied force is then determined in the above described manner. It is believed that the detection of rotational displacement of the lower back of the patient P in more than one plane will provide useful diagnostic information.

With reference to FIGS. 8(a)-8(c), a pair of non-elastic metal blocks 138 are separated by and secured to a calibration rod 140 having a desired elasticity. To calibrate the examination table A one of the blocks 138 is positioned between the first pad 54 and second pad 56. The other of the blocks 138 is positioned on the patient receiving side 4 of the examination table A and is, preferably, secured thereto. The blocks 138 are preferably positioned on the table A so that the longitudinal axis of the calibration rod 140 is positioned above and in alignment with the longitudinal axis of the examination table A. A laser 84 is positioned on the one of the blocks 138 positioned between the first pad 54 and second pad 56. The laser 84 is projected onto a scaled chart 100 or the optical array 130. Clockwise and counterclockwise rotational torques are incrementally applied to the calibration bar 140 by forcibly extending the first pad 54 and then the second pad 56 into the one of the blocks 138 positioned between the pads 54, 56. The projection of the laser 84 on the chart 100 or optical array 130 in response the forcible extension is detected for each increment. A plot on a Cartesian coordinate system of clockwise displacement and counterclockwise displacement as a function of applied force reveals a substantially linear relationship therebetween. This substantially linear relationship indicates that the examination table A contributes minimal or predictable artifacts to the hysteresis loops, e.g., 114, 116.

It can be seen from the foregoing that the present invention is an anatomic torsion monitor that can provide a quantitative measurement of the myofascial-musculoskeletal elasticity. The present invention also provides a method for detecting elasticity of muscles, ligaments and myofascial structure in a patient.

It is believed that the above-described invention, and specifically the embodiment shown in FIG. 5, can be connected to a central data collection computer. Such central data collection computer can be utilized to obtain data regarding rotational displacement versus force for a plurality of patients from a plurality of anatomic torsion monitors. This data can then be utilized by the central data collection computer for correlated purposes.

The invention has been described with reference to the preferred embodiments. Obvious modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations, insofar as they come within the scope of the appended claims or the equivalents thereof.

We claim:

1. An anatomic torsion apparatus for detecting myofascial-musculoskeletal elasticity, the torsion apparatus comprising:

an examination table for positioning a patient so that the muscles associated with a portion of the anatomy of the patient are relaxed;

12

a rotational torque means for applying to the portion of the anatomy a rotational torque in a first direction and a rotational torque in a second direction opposite the first direction, with the rotational torque means including a first pad forcibly extendable transverse to a plane of the examination table and a second pad forcibly extendable transverse to the plane of the examination table; and a rotational displacement measuring means for measuring a rotational displacement of the portion of the anatomy in response to the application and removal of the rotational torque in the first direction and the application and removal of the rotational torque in the second direction, wherein:

one of the first pad and the second pad is individually forcibly extended in the absence of the other of the first pad and the second pad being forcibly extended, and vice versa, whereby the rotational torque in the first direction is applied in the absence of rotational torque in the second direction and rotational torque in the second direction is applied in the absence of rotational torque in the first direction; and the first pad and the second pad, when contracted, are substantially coplanar with the plane of the examination table.

2. The anatomic torsion apparatus as set forth in claim 1, wherein the rotational torque in one of the first direction and the second direction is applied transverse to the longitudinal axis of the portion of the anatomy.

3. The anatomic torsion apparatus as set forth in claim 1, wherein the portion of the anatomy is a spine of a patient including associated structure.

4. The anatomic torsion apparatus as set forth in claim 1, wherein the first pad and the second pad are positionable to contact the posterior-superior iliac spines.

5. The anatomic torsion apparatus as set forth in claim 1, wherein the forcible extension of one of the first pad and the second pad causes rotation about the transverse axis of the patient.

6. The anatomic torsion apparatus as set forth in claim 1, further including a calibration means positioned between the rotational torque means and the rotational displacement measuring means for causing the rotational displacement measuring means to undergo a known rotational displacement in response to the application by the rotational torque means of a known rotational torque to the calibration means.

7. The anatomic torsion apparatus as set forth in claim 1, wherein the rotational displacement measuring means includes:

a pointer positionable to rotate with the anatomy and point one of (i) transverse to a longitudinal axis of the anatomy and (ii) parallel with a longitudinal axis of the anatomy; and

a detector which detects rotational displacement of the pointer during rotation of the anatomy.

8. The anatomic torsion apparatus as set forth in claim 7, wherein the pointer is a laser and the detector is one of a scaled chart and an optical array positioned to receive an output of the laser.

9. The anatomic torsion apparatus as set forth in claim 7, further including a platform positionable on the anatomy and supporting the pointer during rotation of the anatomy.

10. The anatomic torsion apparatus as set forth in claim 9, further including a standoff disposed on opposite ends of the platform on the side of the platform opposite the pointer, wherein the portion of the anatomy is a spine of a patient, and wherein the sides of each standoff opposite the platform are positionable on the anterior-superior iliac spines.

13

11. The anatomic torsion apparatus as set forth in claim 10, wherein the platform and the anatomy form a gap therebetween.

12. An examination table for detecting elasticity of muscles, the examination table comprising:

a table having a receiving side for receiving a supine patient thereon;

a pair of pads spaced from each other and positioned laterally to a longitudinal axis of the table, with each pad having an upper surface positionable substantially coplanar with the receiving side of the table; and

a drive means for forcibly extending one pad away from the receiving side of the table in the absence of forcible extension of the other pad, and vice versa, the upper surface of the one pad remaining substantially coplanar with the receiving side of the table when the other pad is forcibly extended and with the other pad remaining substantially coplanar with the receiving side of the table when the one pad is forcibly extended, wherein:

the patient is receivable on the receiving side of the table with the one pad contacting a right-posterior-superior iliac spine (RPSIS) of the patient and with the other pad contacting a left-posterior-superior iliac spine (LPSIS) of the patient;

the forcible extension of the one pad causes the patient to rotate about a transverse axis of the patient in a first direction, with the RPSIS of the patient moving away from the receiving side of the table; and

the forcible extension of the other pad causes the patient to rotate about the transverse axis of the patient in a second direction opposite the first direction, with the LPSIS of the patient moving away from the receiving side of the table.

13. The examination table as set forth in claim 12, wherein:

the drive means includes one lever having a first end attached to a side of the one pad opposite the receiving side of the table and pivotable about a point between the first end and a second end thereof;

the first end of one lever experiences an upward force in response to the application of a downward force at the second end of the one lever;

the drive means includes another lever having a first end attached to a side of the other pad opposite the receiving side of the table and pivotable about a point between the first end and second end thereof; and

the first end of the other lever experiences an upward force in response to the application of a downward force at the second end of the other lever.

14. The examination table as set forth in claim 12, wherein the drive means includes one of:

- (i) an electric motor and cam;
- (ii) a linear electric motor; and
- (iii) a hydraulic apparatus.

15. The examination table as set forth in claim 12, further including:

a controller;

a laser; and

an optical array, wherein:

the laser is secured to an anterior-superior iliac spine of the patient;

the optical array is positioned to receive light output by the laser; and

the controller coordinates the operation of the drive means and the optical array to obtain readings from the optical array indicative of the rotational displacement of the patient as a function of the forcible extension of the one pad or the other pad.

16. The examination table as set forth in claim 12, further

15 including a gimbal ring connected between the one pad and the drive means, the gimbal ring enabling the one pad to pivot with respect to the receiving side of the table when the one pad is forcibly extended therefrom.

17. A method of detecting the elasticity of muscles in a patient, the method comprising the steps of:

applying to a supine patient received on a planar surface a first force which causes rotation about the patient's transverse axis in a first direction;

measuring the rotational displacement of the patient about the transverse axis as a function of the applied first force;

removing the first force;

measuring the rotational displacement of the patient in the absence of an applied force;

applying to the supine patient a second force which causes rotation about the patient's transverse axis in a second direction opposite the first direction;

measuring the rotational displacement of the patient about the transverse axis as a function of the applied second force;

removing the second force; and

measuring the rotational displacement of the patient in the absence of an applied force.

18. The method as set forth in claim 17, further including the step of:

forming a plot of the measured rotational displacement as a function of the first force and the measured rotational displacement as a function of the second force.

19. The method as set forth in claim 17, further including the step of:

determining the rotational displacement of the patient in the first direction and the second direction as a function of time.

20. The method as set forth in claim 19, further including the step of:

Fourier transforming the rotational displacement of the patient in the first direction and the second direction as a function of time.

* * * * *



US007833142B2

(12) **United States Patent**
Karp(10) **Patent No.:** **US 7,833,142 B2**
(45) **Date of Patent:** **Nov. 16, 2010**

(54) **METHODS AND APPARATUS FOR TESTING ABDOMINAL STRENGTH AND EXERCISING ABDOMINAL MUSCLES**

5,304,109 A 4/1994 Shockley
5,338,276 A * 8/1994 Jull et al. 482/113
5,515,865 A 5/1996 Scanlon

(76) Inventor: **Shaun A. Karp**, P.O. Box 47518,
Coquitlam, BC (CA) V3K 6T3

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 257 days.

(21) Appl. No.: **11/996,288**

WO 0126506 A2 4/2001

(22) PCT Filed: **Jul. 19, 2006**

(Continued)

FOREIGN PATENT DOCUMENTS

(86) PCT No.: **PCT/CA2006/001185**

§ 371 (c)(1),
(2), (4) Date: **May 9, 2008**

(Continued)

(87) PCT Pub. No.: **WO2007/009244**

OTHER PUBLICATIONS

PCT Pub. Date: **Jan. 25, 2007**

International Search Report for PCT/CA2006/001185, International Searching Authority, Nov. 22, 2006, pp. 1-4.

(65) **Prior Publication Data**

US 2008/0214372 A1 Sep. 4, 2008

Primary Examiner—Lori Baker

(74) Attorney, Agent, or Firm—Oyen Wiggs Green & Mutala LLP

(51) **Int. Cl.**

A63B 26/00 (2006.01)

ABSTRACT

(52) **U.S. Cl.** **482/140**; 482/23; 446/220

An abdominal mat has a raised section which may be positioned to support the lumbar region of the user's back. At least one sensor is associated with the raised section for producing a signal in response to force applied to the raised section by the user. A feedback device is coupled to the sensor for providing feedback to the user based on the force applied to the raised section. A user may use the device to test the strength of his or her abdominal muscles, and/or to monitor the force applied to the raised section of the mat when the user is exercising his or her abdominal muscles. The raised section may comprise an inflatable bladder connected to be automatically inflated and deflated by an electronic pump to accommodate different body types, therefore establishing a consistent starting point.

(58) **Field of Classification Search** 482/140,

482/91, 907, 142, 1-9, 111; 601/26, 148,
601/49, 56-60; 600/587, 594; 297/284.1,
297/284.7; 340/573.1, 573.7; 5/621, 630,
5/636-638, 640, 922, 940

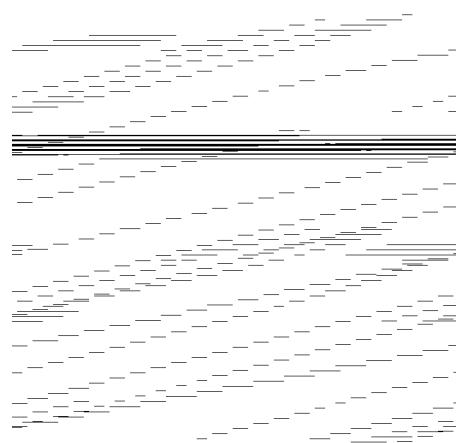
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

515,865 A * 3/1894 Scanlon 229/123.2
3,325,799 A 6/1967 Farris
4,326,506 A 4/1982 Kawabata
4,759,543 A 7/1988 Feldman
4,905,990 A 3/1990 DeSantis

31 Claims, 8 Drawing Sheets



U.S. PATENT DOCUMENTS

5,674,238 A * 10/1997 Sample et al. 606/192
5,755,647 A * 5/1998 Watnik 482/142
5,785,669 A * 7/1998 Proctor et al. 601/148
5,845,644 A 12/1998 Hughes et al.
6,019,738 A * 2/2000 Brandon 600/587
6,117,095 A 9/2000 Daggett et al.
6,384,729 B1 5/2002 Plotkin
6,479,727 B1 11/2002 Roe
6,648,838 B1 * 11/2003 Brandon et al. 600/587
6,876,883 B2 4/2005 Hurtado
2001/0020143 A1 9/2001 Stark et al.
2002/0098958 A1 7/2002 Watnik
2004/0056520 A1 3/2004 Cho

2004/0097837 A1 5/2004 Brandon et al.
2004/0152957 A1 8/2004 Stivoric et al.
2004/0195876 A1 10/2004 Huiban
2004/0201487 A1 10/2004 Benson et al.
2005/0043660 A1 2/2005 Stark et al.
2005/0137462 A1 6/2005 Cho
2006/0132382 A1 6/2006 Jannard
2006/0150752 A1 7/2006 Lorenz et al.
2006/0208169 A1 9/2006 Breed et al.
2006/0265941 A1 11/2006 Newton

FOREIGN PATENT DOCUMENTS

WO 2004002313 A1 1/2004

* cited by examiner

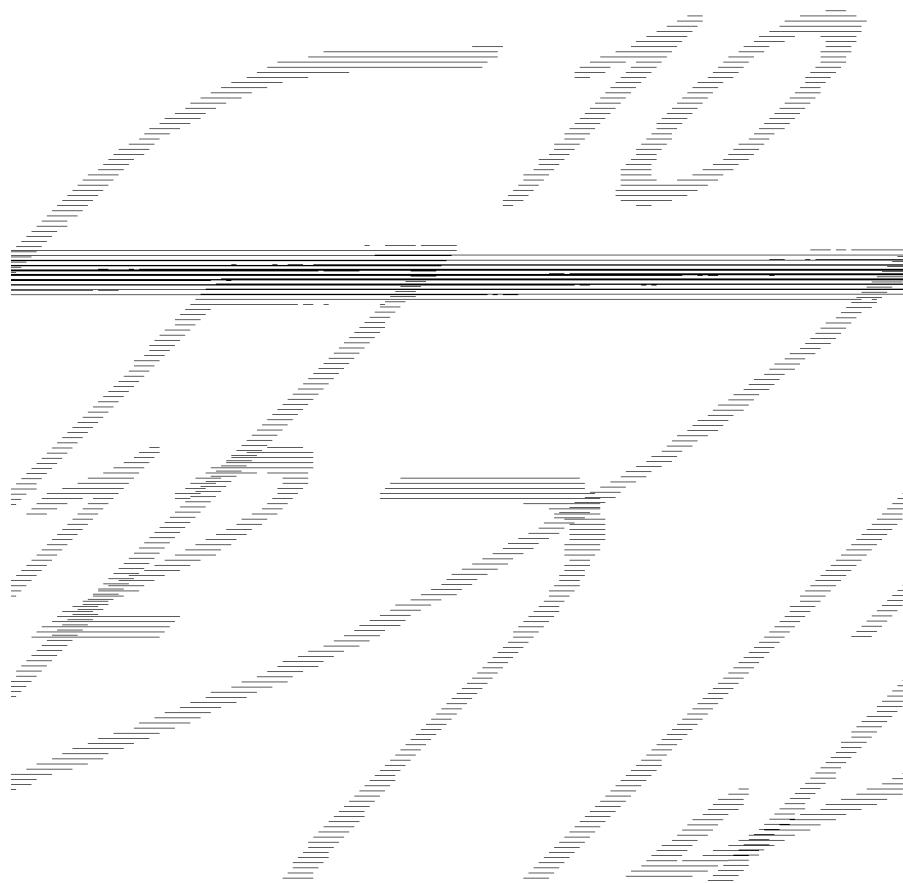


Figure 1





Figure 3

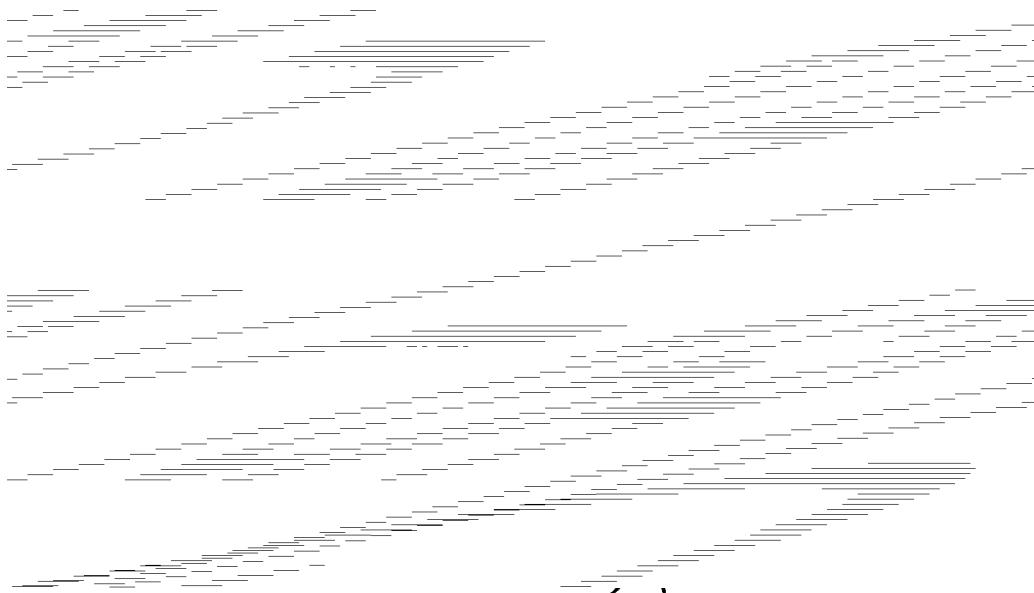


Figure 5 21 18



Figure 6

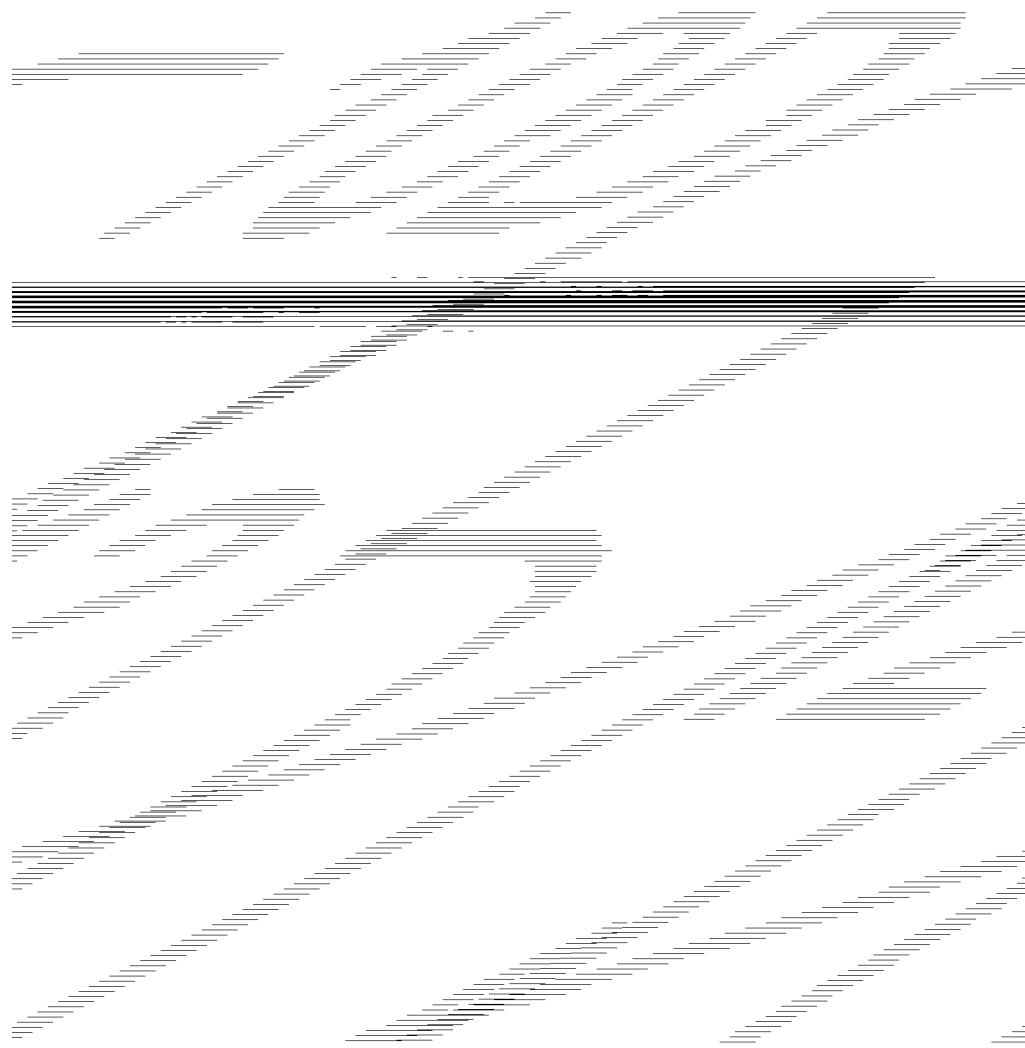


Figure 6A



Figure 7



Figure 8

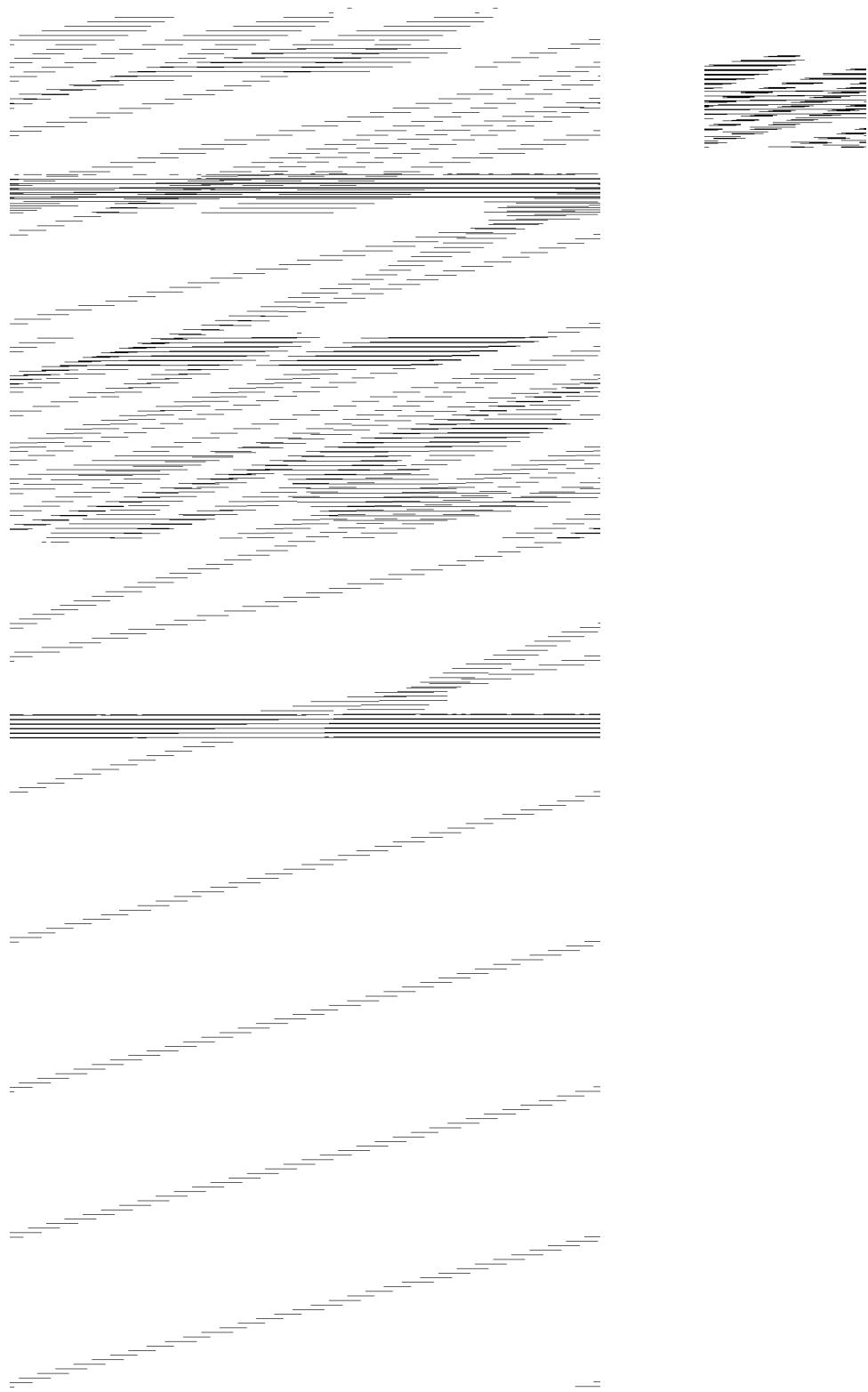


Figure 9



Figure 10

1

**METHODS AND APPARATUS FOR TESTING
ABDOMINAL STRENGTH AND EXERCISING
ABDOMINAL MUSCLES**

TECHNICAL FIELD

The invention relates to abdominal fitness, and to exercise mats.

BACKGROUND

Proper abdominal strength is required to help maintain normal trunk posture and function as well as to prevent injury, particularly to the lower back. A variety of exercises can be utilized to strengthen the abdominal muscles. Such exercises include, but are not limited to: conventional sit ups, crunches (partial sit ups), leg raises lying supine (with knees bent or straight), torso twists, hanging leg raises, pelvic tilts, kneeling crunches using cable resistance, exercises using abdominal sit up machines, etc.

In the process of abdominal conditioning, it is desirable for the individual to do exercises appropriate for their level of abdominal strength and coordination to prevent injury and to facilitate optimal strengthening. There exist a number of prior art devices which a user may use to assist with exercising his or her abdominal muscles.

For example, U.S. Pat. No. 5,755,647 to Watnik discloses an exercise appliance which includes a structure presenting a resiliently yieldable contact surface having a contour suitably sized and shaped to be at least partially fittable in the space formed between a support surface and a static lordotic curve of a lumbar back of an individual. The appliance may also be provided with means for providing feedback in response to compression of the appliance.

Other examples of prior art apparatus relating to abdominal fitness include U.S. Pat. Nos. 6,648,838, 6,117,095, 6,019, 738, 5,785,669, 5,515,865, 5,304,109, 4,905,990, 4,759,543, and 3,325,799, U.S. Patent Application Publications No. 2005/0043660 and No. 2001/0020143, and PCT Publications No. WO 2001/26506 and No. WO 2004/002313.

Although there exist devices designed to strengthen the abdominal muscles, and many exercises designed to do the same, the inventor has determined that there is a need for accurate abdominal muscle strength testing which is vital for appropriate exercise recommendations and is also useful for monitoring rehabilitation, research and the like.

SUMMARY

The following embodiments and aspects thereof are described and illustrated in conjunction with systems, tools and methods which are meant to be exemplary and illustrative, not limiting in scope. In various embodiments, one or more of the above-described problems have been reduced or eliminated, while other embodiments are directed to other improvements.

One aspect of the invention provides an abdominal strength testing and exercising device. The device comprises a support having a raised section for supporting a lumbar portion of a user's back, a sensor associated with the raised section of the support for producing a signal in response to a force applied to the raised section, and a feedback device adapted to receive the signal from the sensor for providing the user with feedback when the force applied to the raised section exceeds a threshold.

Another aspect of the invention provides a method of testing a user's abdominal muscle strength. The method com-

2

pries providing a support having a raised section for supporting a lumbar portion of a user's back, receiving a user-selected threshold force, determining a force dependent value indicative of a force applied to the raised section, and providing feedback to the user if the force dependent value indicates that the force applied to the raised section is at least as strong as the user-selected threshold.

Further aspects of the invention and features of embodiments of the invention are described herein and/or shown in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments are illustrated in referenced figures of the drawings. It is intended that the embodiments and figures disclosed herein are to be considered illustrative rather than restrictive.

In drawings which illustrate non-limiting embodiments of the invention:

FIG. 1 is a top view of an exercising and strength testing device according to one embodiment of the invention;

FIG. 2 is a side view of the device of FIG. 1;

FIG. 3 is a top view of an exercising and strength testing device according to another embodiment of the invention;

FIG. 4 is a side view of the device of FIG. 3;

FIG. 5 is a side view of an exercising and strength testing device according to another embodiment of the invention;

FIG. 6 is a top view of an exercising and strength testing device according to another embodiment of the invention;

FIG. 6A is a top view of an exercising and strength testing device according to another embodiment of the invention;

FIG. 7 schematically illustrates the components of a feedback device according to one embodiment of the invention;

FIG. 8 is a flowchart illustrating a method according to one embodiment of the invention;

FIG. 9 is a flowchart illustrating a method according to another embodiment of the invention; and,

FIG. 10 shows a bench according to another embodiment of the invention.

DESCRIPTION

Throughout the following description specific details are set forth in order to provide a more thorough understanding to persons skilled in the art. However, well known elements may not have been shown or described in detail to avoid unnecessarily obscuring the disclosure. Accordingly, the description and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

The invention provides devices for exercising and testing the strength of users' abdominal muscles. An example device comprises an abdominal mat. The mat has a raised section which may be positioned to support the lumbar region of the user's back. At least one sensor is provided for determining a force applied by the user to the raised section. A feedback device is coupled to the sensor. The feedback device provides feedback to the user or another person working with the user based on the force applied to the raised section. In some embodiments the feedback device comprises a display which indicates a magnitude of the applied force on a non-linear scale. A user may use the device to test the strength of his or her abdominal muscles, and/or to monitor the force applied to the raised section of the mat when the user is exercising his or her abdominal muscles.

FIGS. 1 and 2 show a device 10 according to one embodiment of the invention. Device 10 comprises a mat 12 having a raised section 14. Raised section 14 is positioned to support

the lumbar region of a user's back when the user lies on mat 12. A feedback device 16 is embedded in mat 12 and coupled to raised section 14 by means of a connector 15. Mat 12 may be foldable as indicated by fold lines 18. Fold lines 18 may or may not be symmetrically positioned with respect to mat 12 or raised section 14.

In the embodiment of FIGS. 1 and 2, raised section 14 comprises an inflatable bladder 19 filled with a fluid, such as for example, air. Device 10 may also comprise means for varying the pressure in inflatable bladder 19, such as for example, a hand pump 11 coupled to inflatable bladder 19 through a valve assembly 13. Valve assembly 13 may be configured to seal to prevent fluid from escaping from inflatable bladder 19 when hand pump 11 is removed from mat 12. Valve assembly 13 also allows the user to bleed air or other fluid out of inflatable bladder 19 to reduce the pressure of the fluid in inflatable bladder 19. The user may use hand pump 11 and valve assembly 13 to select a desired initial pressure of the fluid in raised section 14. The desired pressure may be, for example, about 50 to 60 mmHg (relative to atmospheric pressure). The amount of fluid will depend on the user's size and body type as well as on the dimensions of raised section 14. It has been found that a pressure of about 60 mmHg is satisfactory for use by users having a wide range of body sizes and types.

A basic pressure of 60 mmHg allows a person to maintain a neutral spine posture while also feeling sufficient pressure from bladder 19 against the lower back to be able to use device 10 effectively. If the pressure in bladder 19 is too low then the person's spine will tend to flatten out. This, in turn, may provide results that do not indicate abdominal strength available for activities conducted with the spine in a neutral posture (as is the case for most day-to-day activities).

Device 10 also comprises one or more sensors 22 (see FIG. 6) associated with raised section 14. The sensor(s) are configured to produce a signal in response to force applied to raised section 14, and may be positioned in, on, or under raised section 14, in mat 12 adjacent raised section 14, in connector 15, or in feedback device 16. In one configuration, a sensor 22 senses a pressure within bladder 19. In some embodiments, connector 15 comprises a hose in fluid communication with the inside of inflatable bladder 19 of raised section 14, and a sensor is provided in feedback device 16 for measuring the pressure of the fluid in the hose. Alternatively, a pressure sensor could be positioned in fluid communication with bladder 19 in a suitable location such as in connector 15, directly within inflatable bladder 19 of raised section 14, or adjacent to inflatable bladder 19. In the further alternative, a force sensor may be provided on raised section 14 to measure directly a force applied to raised section 14 by a user's lower back.

FIGS. 3 and 4 show a device 10A according to another embodiment of the invention. Device 10A is the same as device 10 of FIGS. 1 and 2, except that in device 10A feedback device 16A is external to mat 12, rather than embedded therein. Feedback device 16A may be supported on a tripod, folding stand, or the like to allow the user to see feedback device 16A when lying on mat 12.

FIG. 5 shows a device 10B according to another embodiment of the invention. Device 10B is the same as device 10A of FIGS. 3 and 4, except that in device 10B connector 15A is replaced with a wireless communication link 17, and one or more pressure sensors and a wireless transmitter 21 coupled to a power source (not shown) are embedded in mat 12 (or raised section 14). Transmitter 21 may comprise an antenna (not shown) embedded in mat 12, depending on the distance between transmitter 21 and feedback device 16B. In the FIG.

5 embodiment, signals from the one or more sensors are provided to transmitter 21 and sent to feedback device 16B by means of communication link 17.

FIG. 6 shows a device 10C according to another embodiment of the invention. Device 10C is the same as device 10A of FIGS. 3 and 4, except that in device 10C hand pump 11 and valve assembly 13 are omitted, and an electronic pump 11C is incorporated into feedback device 16C. Pump 11C is in fluid communication with bladder 19 by means of connector 15C. Pump 11C is controlled to automatically inflate (or inflate and deflate) bladder 19 under the control of feedback device 16C. Pump 11C may be controlled in response to a signal from a pressure sensor. The pressure sensor may be integrated with pump 11C or may be otherwise situated to measure pressure within bladder 19.

In some embodiments, a user prepares device 10C for use by lying on mat 12 in a neutral posture. Either in response to 20 detecting the presence of the user by way of a suitable sensor or in response to the user pressing a button, switch or the like, feedback device 16C causes pump 11C to automatically inflate or deflate bladder 19 to fit the contour of a variety of users large or small so that bladder 19 has a consistent starting 25 pressure in the range of about 50 to 60 mmHg (or some other desired pressure)—preferably about 60 mmHg. When the desired pressure has been reached, feedback device 16C generates a user-detectable signal (such as making a sound, providing tactile feedback, turning on an indicator lamp, or the like) that indicates that device 10C is ready for use. FIG. 6A shows a device 10D according to another embodiment of the invention. Device 10D is the same as device 10C except 30 feedback device 16D and pump 11D are incorporated into mat 12.

FIG. 7 shows an example configuration of feedback device 16 of FIGS. 1 and 2. Feedback device 16A, 16B, or 16C could have a configuration similar to feedback device 16. Feedback 40 device 16 comprises a processor 20 adapted to receive signals from one or more sensors 22 associated with raised section 14. As discussed above, sensors 22 may be positioned in, on or under raised section 14, in mat 12 adjacent raised section 14, in connector 15, or in feedback device 16. Sensors 22 may comprise either analog or digital sensors. Processor 20 determines from the signals from sensors 22 a force-dependent 45 value which is indicative of a force being applied by the user on raised section 14.

Feedback device 16 also comprises an indicator 24 which provides feedback to the user under control of processor 20. Indicator 24 may comprise, for example, an audible indicator such as a buzzer or a speaker, or a visual indicator such as a display screen or a series of lights. In some embodiments indicator 24 comprises a bar graph, a pointer which moves along a scale (the scale may be straight or curved). In some embodiments indicator 24 comprises both audible and visible indicators. In some embodiments, indicator 24 displays a number, or the like words or other indicia that indicate an amount of force being measured by sensors 22.

In preferred embodiments, indicator 24 comprises a non-linear scale. One such scale is shown in Table I. Table I assumes that a sensor 22 measures a fluid pressure in bladder 19 and that the feedback is indicated on a scale having a minimum value of zero and a maximum value of 10. Separate scales are provided for men and women.

TABLE I

MEN(mmHg)	WOMEN (mmHg)	Scale value
60	60	0
70	65	1
80	75	2
90	85	3
100	95	4
120	110	5
140	125	6
160	140	7
185	155	8
215	180	9
245	210	10

On the scale of Table I, a strength level of "1" indicates very weak abdominal muscles. A strength level of "10" indicates exceedingly strong abdominal muscles. An elite athlete could possibly have a strength level of "10". In the scale of Table I, zero on the scale corresponds to a positive pressure (60 mmHg in this example) and the pressure increment required to reach the next value on the scale increase as the scale values increase.

In some embodiments, multiple graduated scales may be provided. For example, scales may be provided for "beginner", "intermediate", and "advanced" users. A separate scale may be provided for any defined population of users. for example, separate scales may be provided for elite hockey players, male fire fighters or the like.

The same pressure may correspond to zero on each of the scales. The pressures corresponding to a maximum scale value (e.g. "10") may increase from scale-to-scale. A knob, button, switch or other control may be provided to allow a user to select an appropriate scale from the plurality of scales.

The scales may each comprise a median normalized strength scale based on a population study of users of a given level (i.e. beginner, intermediate, advanced). For each level, separate scales may be provided for men and women. The strength level on each non-linear scale may correspond to a percentile rank within that user level (e.g. a strength level of "5" may indicate that the pressure exerted by the user indicates that the strength of the user's abdominal muscles is in the 50th percentile for a population made up of all users belonging to the user level to which the scale corresponds).

Processor 20 may be coupled to a memory 26 storing computer-readable instructions, such that processor 20 may implement methods according to the invention by executing the computer-readable instructions. Processor 20 may also maintain a log of signals from sensors 22 in memory 26. Processor 20 may also be configured to communicate with a computer running software to allow the user to interact with processor 20 and any log stored in memory 26.

Feedback device 16 may also comprise a user interface 28 which may be used by the user to interact with processor 20. User interface 28 may comprise, for example, a dial or a switch with multiple settings. Alternatively or additionally, user interface 28 may comprise a keypad and a display (which may be the same display as used by a visual indicator 24). The display may comprise a plurality of LEDs for indicating a user's strength level on a selected scale, for setting a threshold or a target range, and for indicating the operational mode of device 10. the user may use user interface 28 to turn device 10 on and off, to select between a threshold operation mode and a target operation mode, and to set threshold or target forces, as described below.

In operation, a user lies down on mat 12 and positions raised portion 14 under the curve of his or her spine (i.e.,

under the lumbar region of the user's back). In embodiments comprising an electronically-controlled pump, such as the embodiment of FIG. 6, the pump may operate automatically to inflate or deflate bladder 19 to achieve the desired pressure

5 while the user is lying in a neutral position. An audible and/or visible indication may indicate to the user that the desired pressure has been achieved. The user then selects a scale for measuring strength levels and an operation mode and begins to do exercises.

10 In the threshold mode, the user may either input a force threshold or select one of a plurality of predetermined force thresholds. For example, in embodiments where feedback device 16 (or 16A or 16B or 16C) comprises a dial, the user may move the dial to select one of ten predetermined thresholds (or some other number of predetermined thresholds).

15 In the threshold mode, device 10 provides the user with feedback when a user-selected threshold of force is reached or exceeded by the user pressing his or her lower back against raised section 14. For example, in embodiments where feed-

20 back device 16 comprises an audible indicator, the feedback may comprise a sound such as a beep or a buzz which is generated when the applied force exceeds the threshold, or may comprise a recorded voice which states a value indicative of the applied force, or states some other message such as, for example, "threshold achieved." In embodiments where feedback device 16 comprises a visual indicator, the feedback may comprise, for example, displaying a number or a bar graph indicative of the applied force, or lighting a number of LEDs corresponding to a user's strength level measured on a selected scale. The threshold mode is useful for testing abdominal strength, since the user can determine how high they can set the threshold and still receive feedback from device 10 that indicates that the threshold has been achieved.

25 In the target mode, device 10 provides the user with feed-

30 back when the force applied by the user pressing their lower back against raised section 14 falls outside of a user-selected target range. In the target mode, the user may either input a target range or select from one of a plurality of predetermined target ranges. For example, in embodiments where feedback

35 device 16 (or 16A or 16B or 16C) comprises a dial, the user may move the dial to select one of five predetermined ranges (or some other number of predetermined ranges). In the target mode, device 10 provides the user with feedback when the force exerted by the user pressing his or her lower back

40 against raised section 14 is outside of the user-selected range. For example, in embodiments where feedback device 16 comprises an audible indicator, the feedback may comprise a sound such as a beep or a buzz which is generated when the applied force falls outside of the range, and may also com-

45 prise a warning sound generated when the applied force approaches a boundary of the range. In embodiments where feedback device 16 comprises a visual indicator, the feedback may comprise, for example, displaying a number or a bar graph indicative of the applied force or lighting a number of

50 LEDs corresponding to a user's strength level measure on a selected scale. The target mode is useful for doing exercises where it is desirable to maintain a relatively constant pressure on raised section 14, such as for example leg lifts.

FIG. 8 illustrates a method 100 of providing feedback to 55 the user of an abdominal exercising and strength testing device in a threshold operation mode. Method 100 is described with reference to device 10 of FIGS. 1, 2 and 7, but it is to be understood that method 100 could be carried out with a different embodiment of the invention.

60 Method 100 starts at block 102, for example by the user turning on device 10 and selecting the threshold operation mode. At block 104 processor 20 receives information speci-

fying a force threshold from user input 28. At block 106 a force dependent value indicative of the applied force on raised section 14 is determined by processor 20 based on signals from sensors 22. At block 108 processor determines if the force dependent value determined at block 106 indicates that the force applied to raised section 14 is at least as strong as the threshold force received at block 104. If not (block 108 NO output), method 100 repeats the steps of blocks 104 to 108. If the force dependent value determined at block 106 indicates that the force applied to raised section 14 is at least as strong as the force threshold received at block 104 (block 108 YES output), method 100 proceeds to block 110 where processor 20 causes indicator 24 to provide feedback to the user indicating that the force threshold has been reached. Method 100 then returns to block 104. In some situations, the user may wish to do multiple repetitions of an exercise using the same force threshold. In such situations, the user can select the force threshold initially using user input 28, then leave the force threshold set while exercising.

FIG. 9 illustrates a method 200 of providing feedback to the user of an abdominal exercising and strength testing device in a target operation mode. Method 200 is described with reference to device 10 of FIGS. 1, 2 and 7, but it is to be understood that method 200 could be carried out with a different embodiment of the invention.

Method 200 starts at block 202, for example by the user turning on device 10 and selecting the target operation mode. At block 204 processor 20 receives information specifying a target force range from user input 28. At block 206 a force dependent value indicative of the applied force on raised section 14 is determined by processor 20 based on signals from sensors 22. At block 208 processor determines if the force dependent value determined at block 206 indicates that the force applied to raised section 14 is within the target force range received at block 204. If it is (block 208 YES output), method 200 repeats the steps of blocks 204 to 208. If the force dependent value determined at block 206 indicates that the force applied to raised section 14 is outside of the target force range received at block 204 (block 208 NO output), method 200 proceeds to block 210 where processor 20 causes indicator 24 to provide feedback to the user, indicating that the user is applying force to raised section 14 outside of the target force range. Method 200 then returns to block 204.

In an example embodiment, a user first sets a strength level. This may be achieved by selecting a threshold as described above and pressing down on raised section 14. Device 10 beeps if the threshold is achieved. The user can increase the threshold until he or she determines the largest achievable threshold. Next, the user places device 10 in a strength mode. In this mode the user may perform repetitions of an exercise. In each repetition the user works to cause device 10 to beep, thus indicating that the user has achieved a set pressure. In a third mode the user can perform an exercise which requires the user to maintain a steady pressure on raised section 14. In this mode device 10 beeps if the user is pushing too hard or not hard enough.

A structure other than a mat may be used as a support for the user's back. For example, FIG. 10 shows a device 30 according to another embodiment of the invention. Device 30 comprises a bench 32 having a raised section 34. Raised section 34 may be inflated using hand pump 31, and is coupled to feedback device 36. Device 30 functions just like device 10 of FIGS. 1 and 2, except that bench 32 is not foldable.

A device 10 as described herein responds primarily to forces exerted by a user's lower abdominal muscles. This is advantageous since weakness in the lower abdominal

muscles can be a cause of certain kinds of back pain. The strength of the upper abdominal muscles is not highly relevant to such kinds of back pain.

A device as described herein may be used to assess the strength of a person's lower abdominal muscles and to provide objective measurements of changes in strength of the person's lower abdominal muscles over time.

While a number of exemplary aspects and embodiments have been discussed above, those of skill in the art will recognize certain modifications, permutations, additions and sub-combinations thereof. For example:

although the drawings show a rectangular mat, the mat may have a different shape;

the fluid in bladder 19 may comprise a liquid such as water, or oil, or the like or a mixture of air (or another gas) and a liquid;

the various embodiments described herein each have various features that can be combined in combinations or sub combinations other than those that are expressly described herein.

It is therefore intended that the following appended claims and claims hereafter introduced are interpreted to include all such modifications, permutations, additions and sub-combinations as are within their true spirit and scope.

What is claimed is:

1. An abdominal exercising and strength testing device comprising:

a support having a raised section for supporting a lumbar portion of a user's back, the raised section comprising an inflatable bladder;

a sensor associated with the raised section of the support for producing a signal representative of a magnitude of a force applied to the raised section;

a pump in fluid communication with the bladder, the pump connected to receive the signal from the sensor and automatically pressurize the bladder to a desired pressure based on the signal;

a feedback device adapted to receive the signal from the sensor for providing the user with feedback based on the magnitude of the force applied to the raised section, the feedback comprising a strength level measured on a non-linear scale;

a user interface for receiving: a user-selected operation mode from among a plurality of operation modes comprising a threshold mode and a target mode; a user-selected force threshold; and a user selected target force range;

a processor coupled to the sensor and to the user interface; and

a memory coupled to the processor, the memory containing computer-readable instructions which, when executed by the processor, cause the processor to:

if the user-selected operation mode is the threshold mode, operate the feedback device to provide feedback when the force applied to the raised section exceeds the user-selected force threshold; and,

if the user-selected operation mode is the target mode, operate the feedback device to provide feedback when the force applied to the raised section is outside of the user-selected target force range.

2. A device according to claim 1 wherein the feedback device comprises a user interface comprising a control operable for selecting one of a plurality of scales for measuring the strength level.

9

3. A device according to claim 2 wherein each of the plurality of scales comprises a normalized scale based on a population of users having similar fitness levels.

4. A device according to claim 3 wherein the strength levels on each of the plurality of scales correspond to percentile ranks within the population for that scale.

5. A device according to claim 1 wherein the feedback device comprises an audible indicator for providing the user with audible feedback and wherein the feedback device causes the audible indicator to emit a distinctive sound when the force applied to the raised section exceeds a first threshold.

6. A device according to claim 5 wherein the feedback device causes the audible indicator to emit a distinctive sound when the force applied to the raised section is less than a second threshold which is lower than the first threshold.

7. A device according to claim 6 wherein the feedback device comprises a visual indicator for providing the user with visible feedback.

8. A device according to claim 7 wherein the visual indicator comprises a representation of the non-linear scale and an indicia indicating the strength level.

9. A device according to claim 7 wherein the visual indicator is locatable in a position viewable by the user when lying on the support.

10. A device according to claim 2 wherein the memory is configured for storing one or more previously measured strength levels for a user.

11. A device according to claim 1 wherein the sensor comprises a pressure sensor in fluid communication with the inflatable bladder.

12. A device according to claim 1 wherein the desired pressure is about 60 mmHg.

13. A device according to claim 1 wherein a strength level of zero on the non-linear scale corresponds to a non-zero pressure.

14. A device according to claim 13 wherein, in the non-linear scale, the following pressures correspond to the following strength levels:

a pressure of 60 mmHg corresponds to a strength level of 0; 40
 a pressure of 65 mmHg corresponds to a strength level of 1;
 a pressure of 75 mmHg corresponds to a strength level of 2;
 a pressure of 85 mmHg corresponds to a strength level 3;
 a pressure of 95 mmHg corresponds to a strength level of 4;
 a pressure of 110 mmHg corresponds to a strength level of 45

5;
 a pressure of 125 mmHg corresponds to a strength level of 6;

a pressure of 140 mmHg corresponds to a strength level of 7;

a pressure of 155 mmHg corresponds to a strength level of 8;

a pressure of 180 mmHg corresponds to a strength level of 9; and

a pressure of 210 mmHg corresponds to a strength level of 10.

15. A device according to claim 13 wherein, in the non-linear scale, the following pressures correspond to the following strength levels:

a pressure of 60 mmHg corresponds to a strength level of 0;
 a pressure of 70 mmHg corresponds to a strength level of 1;
 a pressure of 80 mmHg corresponds to a strength level of 2;
 a pressure of 90 mmHg corresponds to a strength level of 3;
 a pressure of 100 mmHg corresponds to a strength level of 4;

a pressure of 120 mmHg corresponds to a strength level of 5;

10

a pressure of 140 mmHg corresponds to a strength level of 6;

a pressure of 160 mmHg corresponds to a strength level of 7;

5 a pressure of 185 mmHg corresponds to a strength level of 8;

a pressure of 215 mmHg corresponds to a strength level of 9; and

a pressure of 245 mmHg corresponds to a strength level of 10.

16. A device according to claim 1 further comprising a hose in fluid communication with the inflatable bladder, wherein the sensor comprises a pressure sensor coupled to the hose.

17. A device according to claim 1 wherein the sensor comprises a pressure sensor embedded in the raised section.

18. A device according to claim 1 wherein the sensor comprises a pressure sensor coupled to a transmitter and a power source embedded in the raised section, and wherein the transmitter provides the signal to the feedback device through a wireless communication link.

19. A device according to claim 1 wherein the support comprises a mat.

20. A device according to claim 19 wherein the mat comprises a plurality of fold lines along which the mat can be folded.

21. A method of testing a user's abdominal muscle strength and exercising the user's abdominal muscles, the method comprising:

providing a support having a raised section for supporting a lumbar portion of a user's back;

receiving a user-selected operation mode, the operation mode comprising one of a threshold mode and a target mode;

if the user-selected operation mode is the threshold mode:
 receiving a user-selected force threshold;
 determining a force dependent value indicative of a

force applied to the raised section; and
 providing feedback to the user if the force dependent value indicates that the force applied to the raised section is at least as strong as the user-selected threshold; and

if the user-selected operation mode is the target mode:
 receiving a user-selected target force range;
 determining the force dependent value indicative of the force applied to the raised section; and

providing feedback to the user if the force dependent value indicates that the force applied to the raised section is outside the user-selected target force range.

22. A method according to claim 21 wherein providing feedback comprises providing audible feedback.

23. A method according to claim 21 wherein providing feedback comprises providing visual feedback.

24. A device according to claim 1 wherein the pump is configured to automatically inflate or deflate the bladder to fit the contour of a user.

25. A device according to claim 7 wherein the visual indicator comprises a bar graph indicative of the applied force.

26. A method according to claim 21, wherein the feedback comprises an indication of a strength level measured on a non-linear scale.

27. A method according to claim 26, wherein the non-linear scale comprises a user-selected non-linear scale and the method comprises receiving a selection of the user-selected non-linear scale from among a plurality of nonlinear scales.

65 28. A method according to claim 26, wherein the non-linear scale comprises an automatically selected non-linear scale and the method comprises automatically selecting the

11

non-linear scale from among a plurality of nonlinear scales based on characteristics of the user.

29. A method according to claim **26** wherein providing feedback comprises providing audible feedback.

30. A method according to claim **26** wherein providing feedback comprises providing visual feedback. 5

12

31. A method according to claim **26** wherein the raised section comprises an inflatable bladder, the method comprising automatically inflating or deflating the inflatable bladder to a desired pressure.

* * * * *



US 20040250618A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2004/0250618 A1**
Keiser (43) **Pub. Date:** **Dec. 16, 2004**

(54) **SYSTEM FOR TESTING MUSCULAR POWER**

(76) Inventor: **Dennis L. Keiser**, Sanger, CA (US)

Correspondence Address:

KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
FOURTEENTH FLOOR
IRVINE, CA 92614 (US)

(21) Appl. No.: **10/694,198**

(22) Filed: **Oct. 27, 2003**

Related U.S. Application Data

(60) Provisional application No. 60/478,499, filed on Jun. 14, 2003. Provisional application No. 60/479,093, filed on Jun. 16, 2003. Provisional application No. 60/482,911, filed on Jun. 25, 2003.

Publication Classification

(51) **Int. Cl.⁷** **A61B 5/22; G01L 5/00**

(52) **U.S. Cl.** **73/379.09; 600/587**

(57)

ABSTRACT

An apparatus and method evaluate the power of a muscle or a muscle group by initializing a resistance element to a first resistance level. An engagement assembly coupled to the resistance element is moved at a highest achievable velocity through an exercise stroke while a representative velocity at which the engagement assembly is moved through the exercise stroke is measured. At the completion of the exercise stroke, the resistance level of the resistance element is increased and the exercise stroke is repeated. The resistance level is increased until the resistance level is sufficient to preclude moving the engagement assembly through a complete exercise stroke. The power for each exercise stroke, the maximum power and the velocity and resistance at which the maximum power is produced are calculated based on the resistance level for each exercise stroke and the representative velocity for each exercise stroke.





FIG. 1

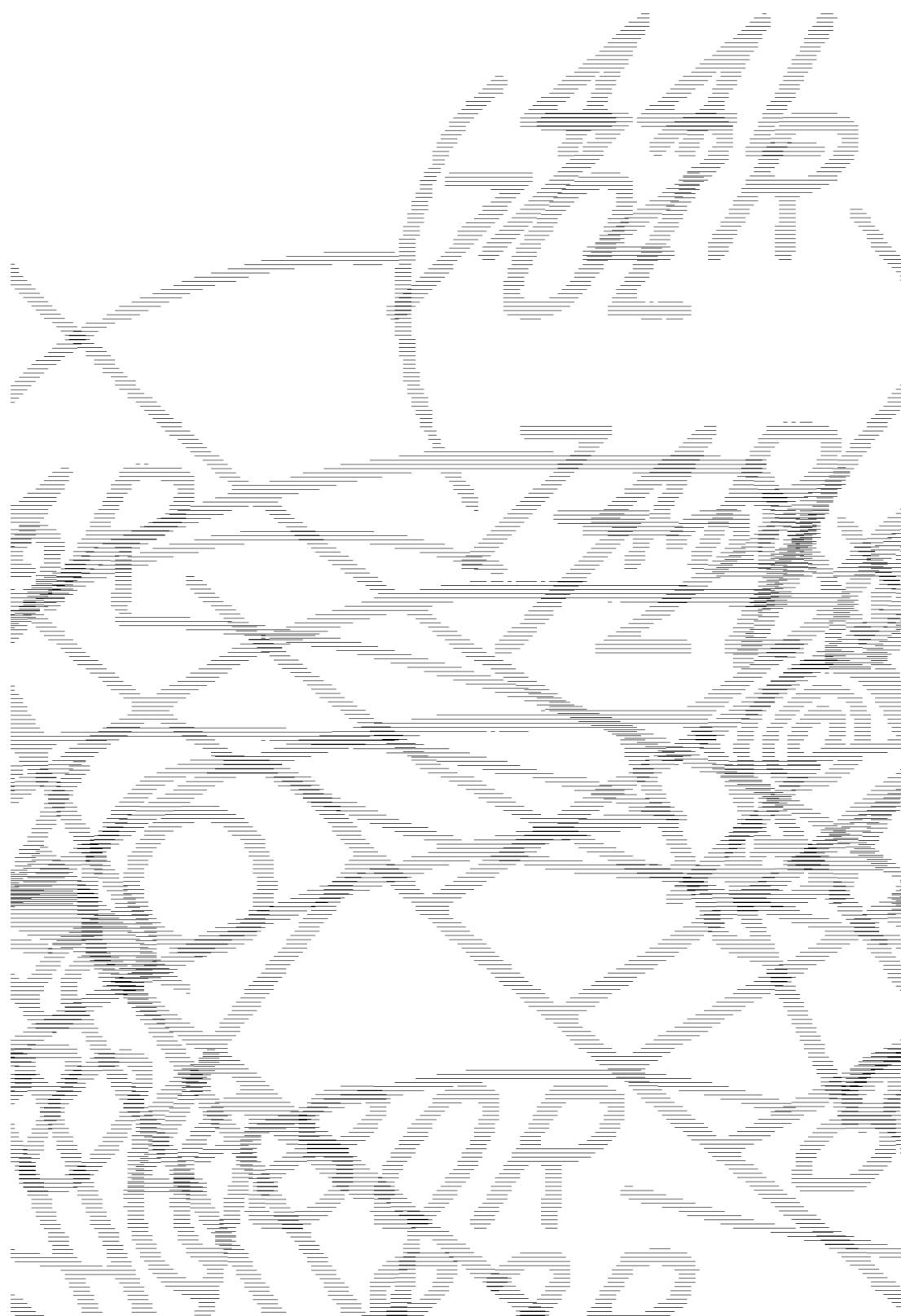
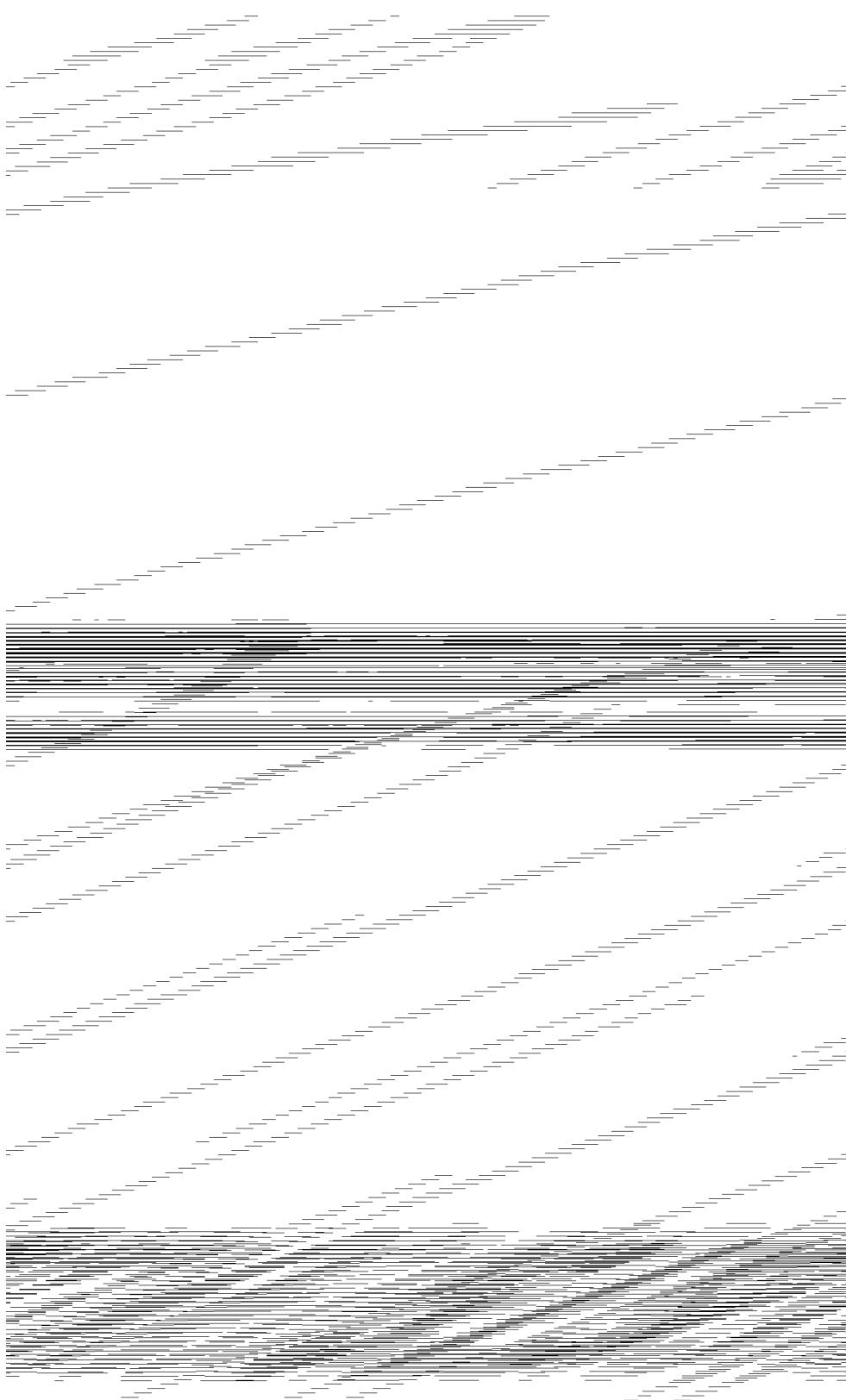


FIG. 2



FIG. 3



162

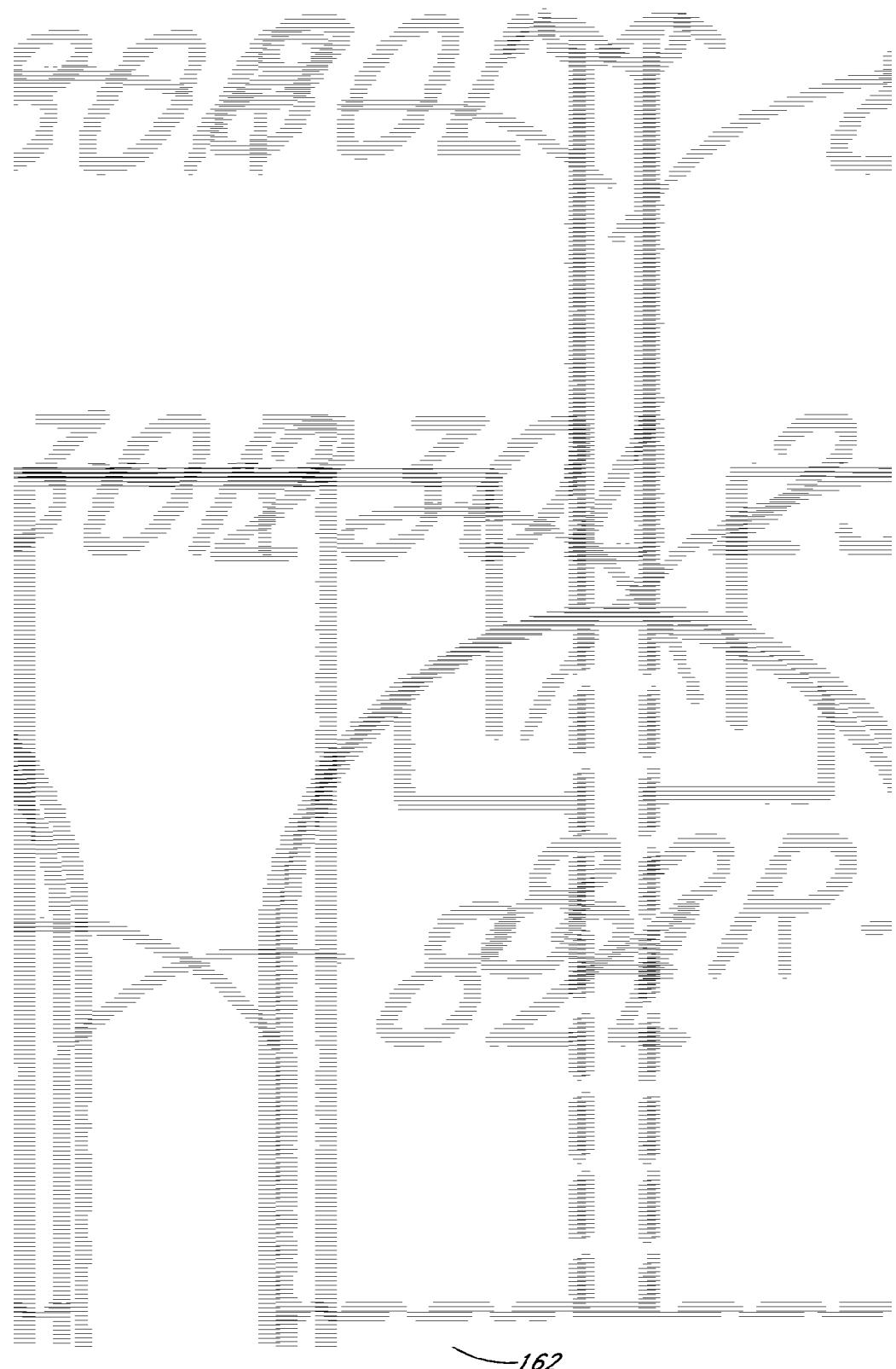


FIG. 5

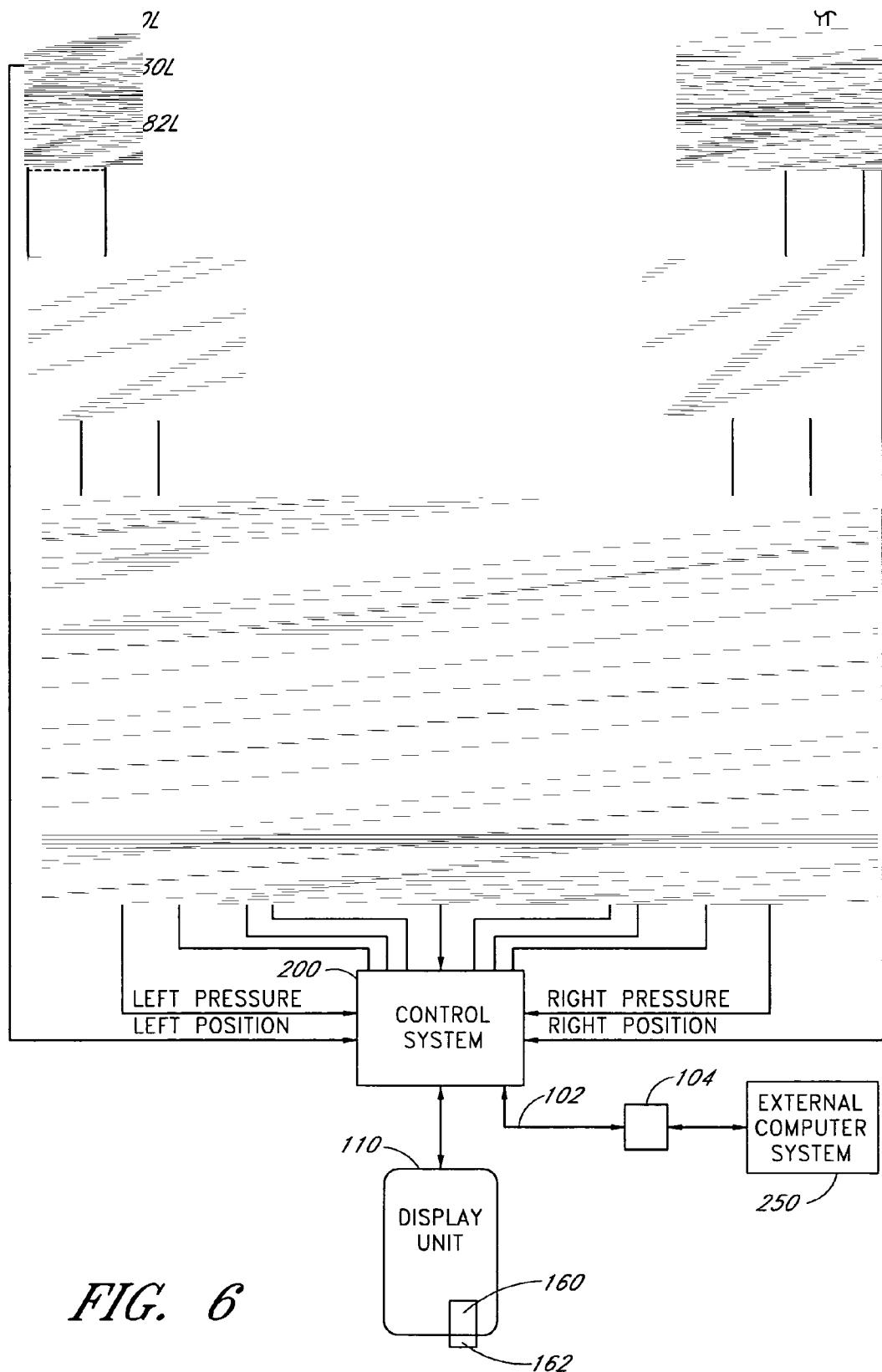


FIG. 6

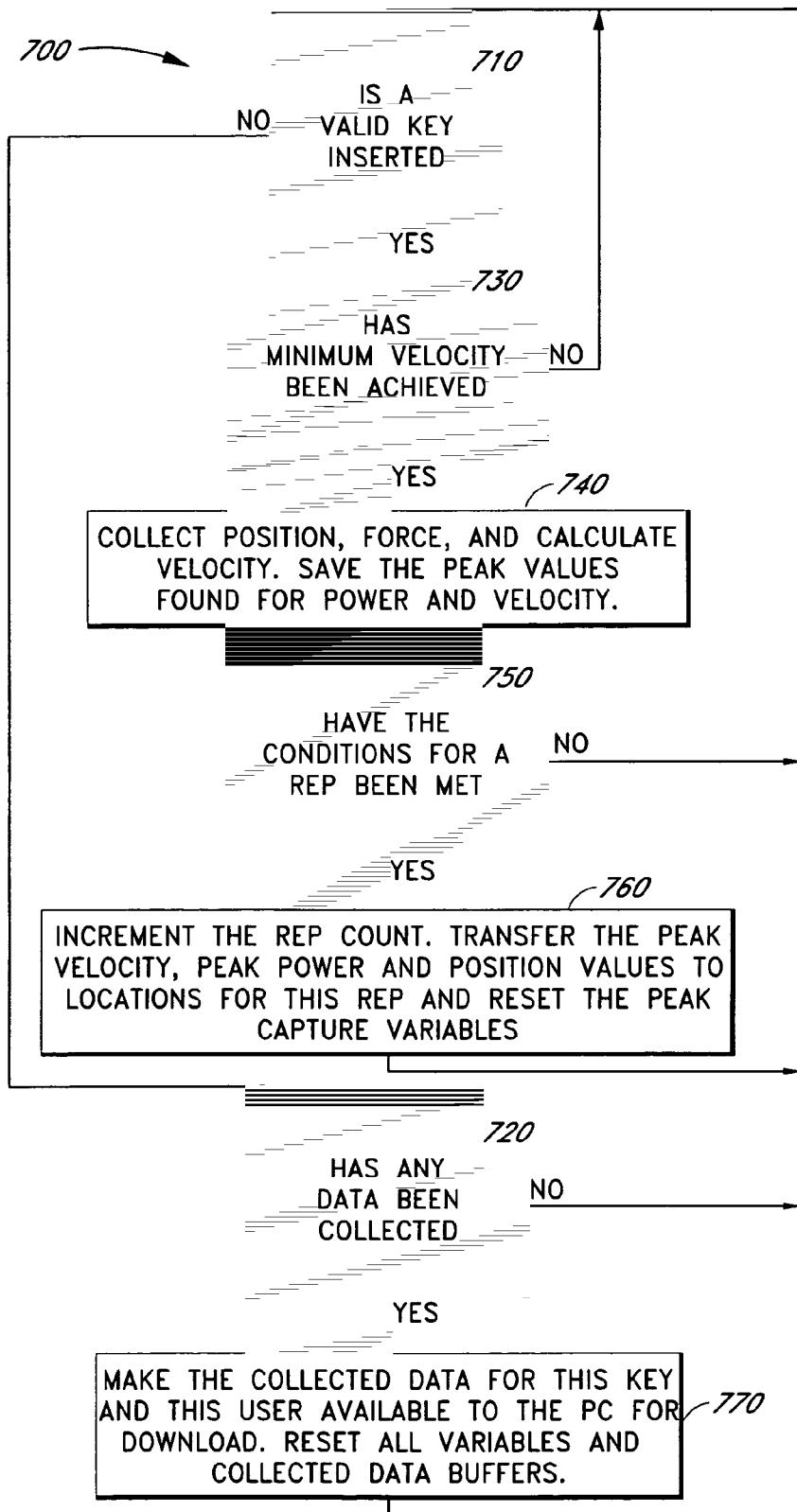


FIG. 7 ROUTINE REPEATED 400 TIMES PER SECOND

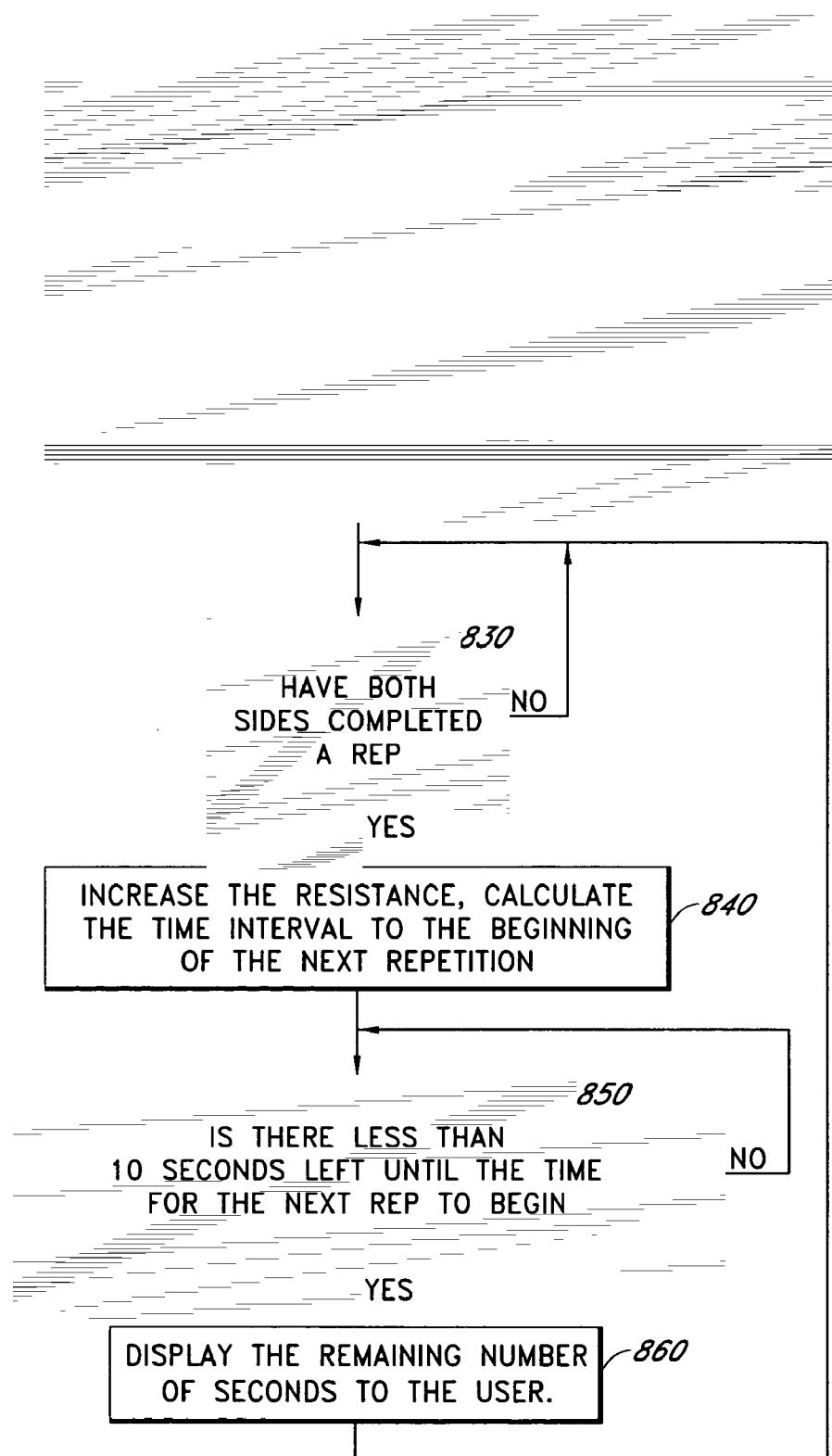


FIG. 8

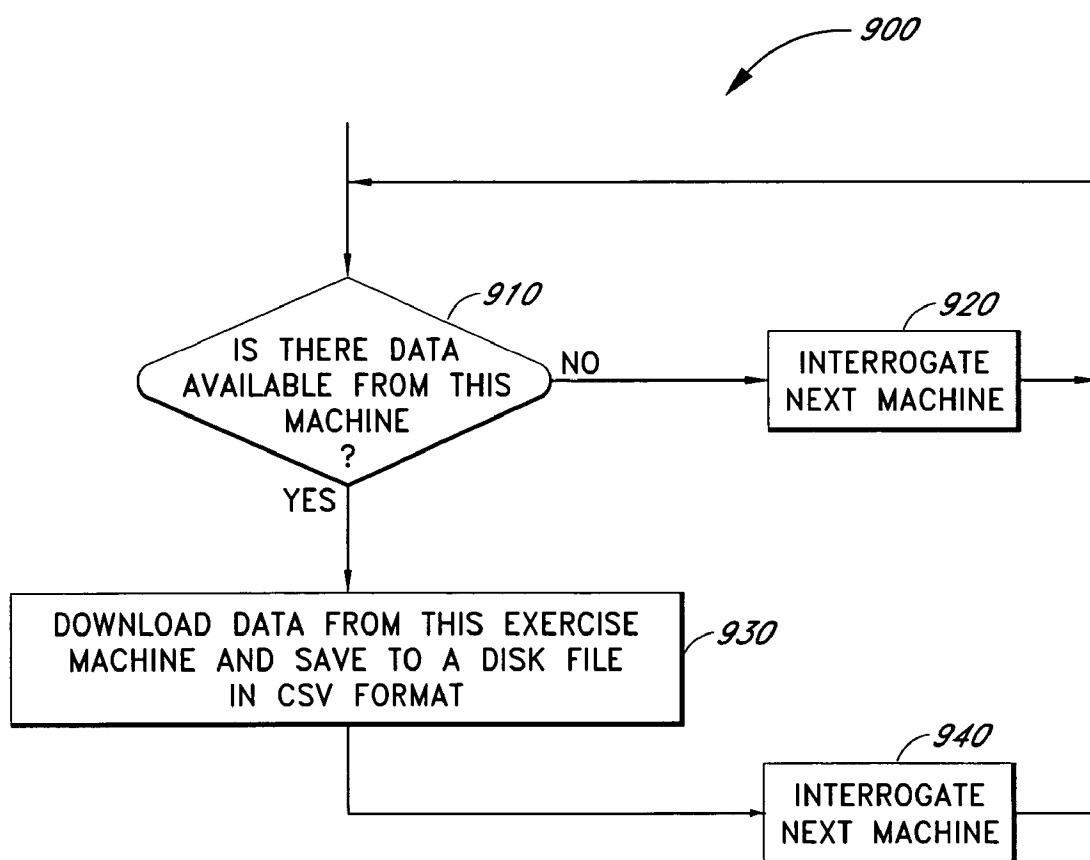


FIG. 9

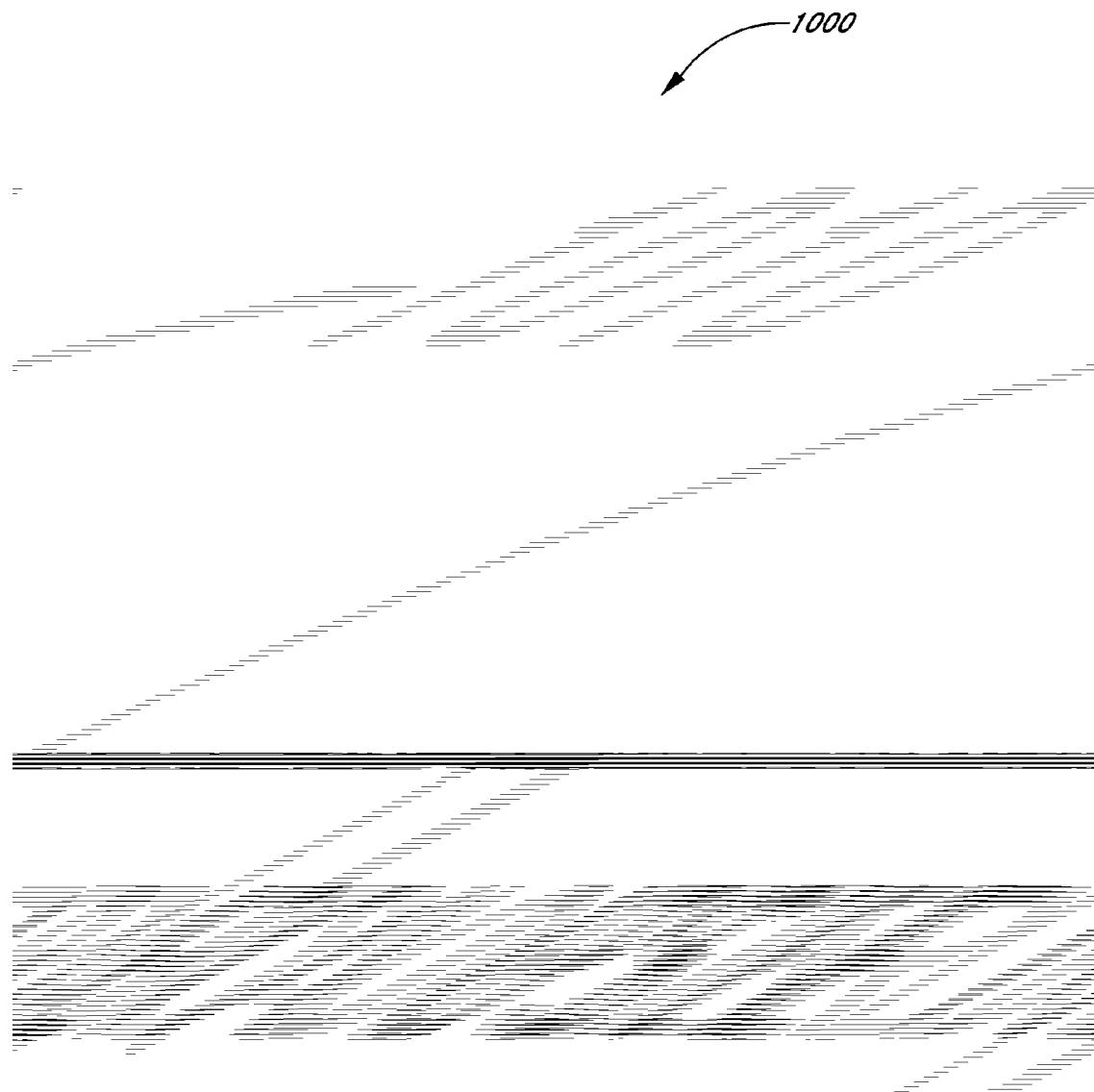
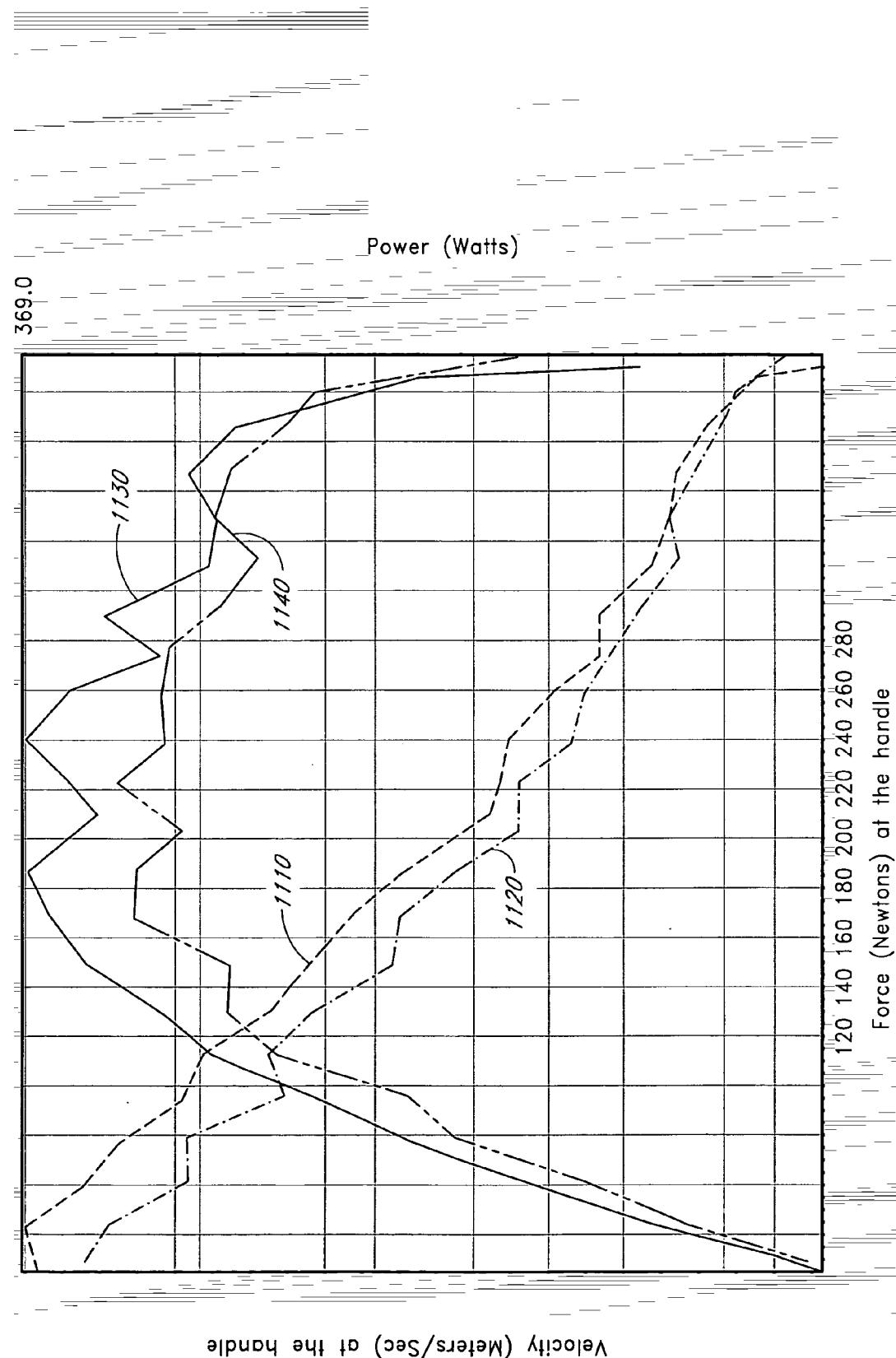


FIG. 10



SYSTEM FOR TESTING MUSCULAR POWER

RELATED APPLICATIONS

[0001] The present application claims the benefit of priority under 35 U.S.C. § 119(e) of U.S. Provisional Application No. 60/478,499, filed on Jun. 14, 2003, U.S. Provisional Application No. 60/479,093, filed on Jun. 16, 2003, and U.S. Provisional Application No. 60/482,911, filed on Jun. 25, 2003.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention is applicable to the fields of fitness, exercise, physical rehabilitation, sports medicine and extremity testing and is directed to methods and apparatuses useable in such fields.

[0004] 2. Description of the Related Art

[0005] Numerous devices have been developed to increase the strength, agility and quickness of athletes and other persons. In addition to enhancing the performance of athletes, such devices are used to improve or maintain the fitness and health of non-athletes, both to enhance the lifestyles of non-athletes and to potentially increase their respective life spans. Such devices range from basic equipment such as barbells, dumbbells, and the like, to increasingly more complex equipment such as universal gyms which enable a user to quickly modify the weights or resistances being used to exercise the user's muscles. See, for example, U.S. Pat. Nos. 4,257,593, 5,526,692 and 5,336,145 to Dennis L. Keiser and U.S. patent application Publication No. US 2002/0024590 A1, which describe exercising apparatuses and related devices using pneumatic devices to provide controllable resistances, and which are incorporated by reference herein. In particular, such pneumatic exercising apparatuses advantageously reduce or eliminate the inertial effects of conventional weights wherein the force required to start moving a weight and the tendency of the weights to continue moving cause the forces required during each exercising stroke to vary throughout the stroke. Such pneumatic apparatuses provide a generally constant resistance throughout the exercising stroke.

[0006] In addition to being used for the development of strength, agility and quickness, exercising apparatuses can be used to measure strength, agility and quickness of a person. For example, a person's ability to lift weights against the force of gravity or a corresponding ability to move against a resistance can be measured at different times to determine whether such characteristics are improving in response to an exercise program or in response to therapy. Such measurements can also be used for evaluation purposes to determine whether one or more muscles or muscle groups are not performing adequately so that a therapist or a fitness trainer, for example, can develop a program of therapy or training more specifically directed to the inadequately performing muscles.

[0007] Historically, measurement and evaluation of muscular performance have concentrated on measuring the strength of a muscle or muscle group (e.g., measuring the amount of weight that can be lifted). However, it has been determined that strength alone does not accurately represent the performance of muscles. A person's muscles may be able

to lift an adequate amount of weight, but may be too slow to be useful for many purposes. For example, an athlete putting the shot at a track and field contest must have the strength to easily move the sixteen-pound shot; however, the strength must be coupled with sufficient speed to cause the shot to be propelled with enough velocity to travel in excess of 70 feet (e.g., 70 feet, 11.25 inches by Randy Barnes at the 1996 Atlanta Olympics). In contrast, some activities require the ability to move very heavy objects at much lower velocities. Thus, although the power requirements may be similar for two activities, the forces and velocities at which the maximum power is required may be different for the two activities.

[0008] From the foregoing it should be understood that a more meaningful measurement of the performance of a person's muscles is a measurement of power (e.g., a measurement of the force applied by the muscles times the velocity of the movement). The average power over an exercise stroke, for example, can be accomplished by timing the duration of the stroke and measuring the distance traveled to determine the average velocity, and then multiplying the average velocity by the force (e.g., the weight moved or the resistance overcome by the muscles). However, because of the structure of most appendages in a person's body, the speed of an exercise stroke will vary throughout the stroke as the appendage varies from full extension to full contraction and the leverage of the muscles against the moving portion of the appendage changes.

SUMMARY OF THE INVENTION

[0009] In view of the foregoing, it can be seen that a need exists for measuring the power exerted by a person's muscles in order to determine the condition of the person's muscles. In addition to determining the maximum power delivered by the muscles, a need exists for determining the force and velocity at which the maximum power is delivered. In some cases, a need also exists for determining the position of the muscles when the maximum power is delivered (e.g., where the muscle and the associated appendage are between maximum extension and maximum contraction).

[0010] In accordance with an aspect of the present invention, a method of evaluating the power of a muscle or a muscle group comprises the act of initializing a resistance element to a first resistance level. The resistance element is coupled to an engagement assembly. The muscle or muscle group to be evaluated is caused to move the engagement assembly at a highest achievable velocity through an exercise stroke. While the exercise stroke is occurring, a representative velocity at which the engagement assembly is moved through the exercise stroke is measured. At the completion of the exercise stroke, the resistance level of the resistance element is increased. The acts of moving, measuring and increasing are repeated until the resistance level is sufficient to preclude moving the engagement assembly through a complete exercise stroke. After the last successful exercise stroke, a power for each exercise stroke is calculated based on the resistance level for each exercise stroke and based on a representative velocity for each exercise stroke. A maximum power is determined, and a velocity and a resistance level where the maximum power is produced are also determined. Preferably, the resistance element is a pneumatic cylinder in which the engagement assembly

causes a piston within the pneumatic cylinder to move against air pressure in the pneumatic cylinder. In one particular embodiment, the engagement assembly is configured as a chest press, wherein a first handgrip is provided for a left hand of a subject and a second handgrip is provided for a right hand of a subject. Each handgrip is coupled to a respective resistance element, and the velocities are measured independently for each handgrip to provide an independent power measurement for each arm of the subject. Preferably, the time between the act of measuring selectively increases as the resistance level increases to enable the muscle group to rest between successive acts of moving the engagement assembly. Preferably, the velocity is determined by periodically measuring a position of a piston in a pneumatic cylinder, and the velocity is calculated based on the distance moved during a known time interval.

[0011] In accordance with another aspect of the present invention, a system for evaluating the power of a muscle group comprises a variable resistance element that can be adjusted to a plurality of resistance levels. An engagement assembly is coupled to the resistance element. During an exercise stroke, the engagement assembly moves against the resistance applied against the engagement by the resistance element. A position transducer is sampled at predetermined time intervals to enable determination of a representative velocity at which the engagement assembly is moved through the exercise stroke at a highest achievable velocity for the applied resistance level. A power calculation system calculates the power for each exercise stroke based on the applied resistance level for each exercise stroke and based on the representative velocity for each exercise stroke. The power calculation system determines a maximum power and determines a velocity and a resistance level at which the maximum power is produced. Preferably, the resistance element is a pneumatic cylinder in which the engagement assembly causes a piston within the pneumatic cylinder to move against air pressure in the pneumatic cylinder. In a particular embodiment, the engagement assembly is configured as a chest press having a first handgrip for a left hand of a subject and having a second handgrip for a right hand of the subject. In the preferred embodiment, the variable resistance element comprises a first resistance element coupled to the first handgrip and a second resistance element coupled to the second handgrip. Each resistance element includes a respective position transducer. In the preferred embodiment, the power calculation system calculates the power independently for each arm of the subject.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Preferred embodiments of the present invention are described below in connection with the accompanying drawing figures in which:

[0013] FIG. 1 illustrates a front view of an exercise and evaluation apparatus in accordance with a preferred embodiment;

[0014] FIG. 2 illustrates a side view of the exercise and evaluation apparatus of FIG. 1;

[0015] FIG. 3 illustrates a side view of the exercise and evaluation apparatus of FIGS. 1 and 2 with the position of a user of the apparatus shown in phantom;

[0016] FIG. 4 illustrates a front view of a display panel for the exercise and evaluation apparatus of FIGS. 1, 2 and 3

and the data key that enables the evaluation features in accordance with a preferred embodiment;

[0017] FIG. 5 illustrates a simplified control diagram in accordance with a preferred embodiment;

[0018] FIG. 6 illustrates a simplified control diagram similar to FIG. 5 but having a different configuration of control valves;

[0019] FIG. 7 illustrates a flow chart of a data gathering routine in accordance with a preferred embodiment;

[0020] FIG. 8 illustrates a flow chart of a power evaluation routine in accordance with a preferred embodiment;

[0021] FIG. 9 illustrates a flow chart of a polling routine for downloading data from a plurality of exercise machines;

[0022] FIG. 10 illustrates a flow chart of a data graphing routine; and

[0023] FIG. 11 illustrates graphs of the left handgrip velocity, the right handgrip velocity, the power of the left arm and the power of the right arm versus applied resistance.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] FIGS. 1, 2, 3 and 4 illustrate an embodiment of an exemplary exercise apparatus 10 that can be used advantageously in connection with embodiments of the present invention for evaluating power generated by a muscle group when moving against levels of resistance that are varied to correspond to varying weights. Although described herein with respect to the apparatus 10, it should be understood that embodiments of the present invention can be incorporated into other exercise apparatuses. For example, the apparatus 10 is configured as a "chest press." The apparatus 10 can also be configured in other suitable configurations. Examples of other exercise equipment on which the performance measurement system can be used include, without limitation, a leg press, a leg extension machine, a leg curl machine, a standing hip machine, an abdominal machine, a lower back machine, an upper back machine, a lateral pull down machine, a military press machine, a triceps machine, an arm curl machine, a seated butterfly machine, a seated calf machine, a lateral shoulder raise machine, a squat machine, and a hip abductor machine, such as the types available commercially from Keiser Corporation, Fresno, Calif.

[0025] The apparatus 10 comprises a frame 12 having a lower portion that rests on a floor of an exercise facility or a fitness evaluation facility. The frame 12 has a generally vertical front portion 20 that supports a seat assembly 22. The seat assembly 22 comprises a seat back portion 24 and a seat bottom portion 26. Preferably, the seat bottom portion 24 is adjustable vertically to accommodate variations in the physical characteristics of users. In alternative embodiments, the seat back portion 26 is also adjustable to accommodate variations in lengths of the users' arms.

[0026] The frame 12 includes a left top portion 30L and a right top portion 30R. The two top portions 30L, 30R are cantilevered over the seat assembly 22. The left top portion 30L has a left hinge 32L positioned at the most forward and upward end. Similarly, the right top portion 30R has a right hinge 32R positioned at the most forward and upward end.

As used herein, "left" and "right" are defined with respect to the position of a user of the apparatus **10**. Thus, when facing the front portion **20** as shown in FIG. 2, the left top portion **30L** and the left hinge **32L** are on the right side of the drawing figure, and the right top portion **30R** and the right hinge **32R** are on the left side of the drawing figure.

[0027] A left lever **40L** is pivotally mounted to the left hinge **32L**, and a right lever **40R** is pivotally mounted to the right hinge **32R**. As described below, the left lever **40L** and the right lever **40R** in combination with their respective components each comprises an independent engagement apparatus for coupling the power from a user to respective resistance elements. The resistance elements are preferably implemented by left and right pneumatic cylinders, which are also described below.

[0028] The left lever **40L** comprises a lower lever portion **42L** that extends generally below and slightly forward of the left hinge **32L**. The left lever **40L** further comprises an upper lever portion **44L** that extends generally above and to the rear of the left hinge **32L**. In the illustrated embodiment, the lower lever portion **42L** and the upper lever portion **44L** comprise a unitary structure having the left hinge **32L** formed at an intermediary location of the structure such that when the lower lever portion **42L** moves forward and generally upward, the upper lever portion **44L** moves rearward and generally downward.

[0029] Preferably, the lower lever portion **42L** includes a hinge **46L** at the lower end thereof. An extended lever portion **48L** pivotally mounted to the lower lever portion **42L** via the hinge **46L**. An adjustment selector **50L** is mounted to the extended lever portion **48L** at the location of the hinge **46L**. The adjustment selector **50L** has a plurality of holes **52L** formed therein (e.g., four holes in the illustrated embodiment). The holes **52L** are selectively engageable with a spring-loaded pin **54L** near the lower end of the lower lever portion **42L**. The spring-loaded pin **54L** can be temporarily disengaged from one of the holes **52L** and the extended lever portion **48L** can be pivoted about the hinge **46L** to change the angle of the extended lever portion **48L** with respect to the lower lever portion **42L** to adapt the position of the extended lever portion **48L** to the physical characteristics of a particular user. The spring-loaded pin **54L** is re-engaged the most closely aligned one of the holes **52L** to restrain the extended lever portion **48L** at the selected angle.

[0030] In like manner, the right lever **40R** comprises elements that generally correspond to the elements of the left lever **40L**. The elements of the right lever **40R** are positioned in similar locations and operate in similar manners as the corresponding elements of the left lever **40L**. In particular, the right lever **40R** comprises a lower lever portion **42R**, an upper lever portion **44R**, a hinge **46R**, and an extended lever portion **48R**. An adjustment selector **50R** has a plurality of holes **52R**. A selectable one of the holes **52R** is engageable with a spring-loaded pin **54R** to adjust the angle of the extended lever portion **48R** with respect to the lower lever portion **42R**.

[0031] In alternative embodiments, the extended lever portions **48L**, **48R** may be positioned at a fixed angle with respect to the respective lower lever portions **42L**, **42R** such that the hinges **46L**, **46R** and the selectors **50L**, **50R** are not needed.

[0032] The left lever **40L** includes a left handgrip **60L** that extends inward (e.g., towards the right) from the left

extended lever portion **48L**. Similarly, the right lever **40R** includes a right handgrip **60R** that extends inward (e.g., towards the left) from the right extended lever portion **166**. In the illustrated embodiment, the handgrips **60L**, **60R** are positioned generally perpendicularly to the respective extended lever portions **48L**, **48R**. Each handgrip **60L**, **60R** has a length sufficient to accommodate the width of a user's hand and to further accommodate variations in the position of a user's hand. Preferably, each handgrip **60L**, **60R** is cylindrical and has a respective gripping surface **62L**, **62R** mounted thereon to assist a user in grasping the handgrips. The gripping surfaces **62L**, **62R** may advantageously be padded for the comfort of the user's hands.

[0033] The exposed end **64L** of the left handgrip **60L** supports a left actuator button **66L**. Similarly, the exposed end **64R** of the right handgrip **60R** supports a right actuator button **66R**. By pressing one of the actuator buttons **66L** or **66R** or by pressing both buttons **66L** and **66R**, a user is able to control various aspects of the operation of the apparatus **10**, which will be discussed below.

[0034] A user seated in the seat assembly **22** is able to grip the handgrips **60L**, **60R** and apply forward forces to the extended lower portions **48L**, **48R** of the levers **40L**, **40R** to cause the extended lower portions **48L**, **48R** to move generally forwardly and upwardly. The levers **40L**, **40R** pivot about the respective hinges **32L**, **32R** such the respective upper lever portions **44L**, **44R** move generally rearward and downward.

[0035] Note that in the illustrated embodiment, the left lever **40L** and the right lever **40R** operate substantially independently. For example, one lever can be moved while the other lever remains at rest. As a further example, the two levers can be moved at different rates.

[0036] A rearmost end **70L** of the left upper lever portion **44L** includes a left upper pivot mount **72L**. The left upper pivot mount **72L** supports a pivot pin **74L**. A left connecting rod **80L** extends from a first end of a left pneumatic cylinder **82L** and is connected to the left upper lever portion **44L** at the left upper pivot mount **72L** via the pivot pin **74L**.

[0037] A second end of the left pneumatic cylinder **82L** includes a lug **84L** having a pivot pin **86L** mounted therein. The pivot pin **86L** engages a left lower pivot mount **88L** on a generally rearward portion of the left top portion **30L** of the frame **12**. Movement of the left upper lever portion **44L** rearwardly and downwardly in response to forward force applied to the left handgrip **60L** by a user causes the left connecting rod **80L** to be moved into the left pneumatic cylinder **82L**. An end (not shown) of the left connecting rod **80L** comprises a piston that slides within the left pneumatic cylinder **82L**. The left connecting rod **80L** and the left pneumatic cylinder **82L** comprise a linear actuator which functions as a resistance assembly for the left lever **40L**. As the left connecting rod **80L** moves into the left pneumatic cylinder **82L**, the left connecting rod **80L** pivots with respect to the left upper pivot mount **72L**, and the second end of the left pneumatic cylinder **82L** pivots with respect to the left lower pivot mount **88L** so that the left connecting rod **80L** can move freely with respect to the left pneumatic cylinder **82L** without binding.

[0038] Similarly, an end **70R** of the right upper lever portion **44R** includes a right upper pivot mount **72R**. The

right upper pivot mount 72R supports a pivot pin 74R. A right connecting rod 80R extends from a first end of a right pneumatic cylinder 82R and is connected to the right upper lever portion 44R at the right upper pivot mount 72R via the pivot pin 72R.

[0039] A second end (not shown) of the right pneumatic cylinder 82R includes a lug (not shown) having a pivot pin (not shown) mounted therein. The pivot pin engages a right lower pivot mount (not shown) on a generally rearward portion of the right top portion 30R of the frame 12. Movement of the right upper lever portion 44R rearwardly and downwardly in response to forward force applied to the right handgrip 60R by a user causes the right connecting rod 80R to be moved into the right pneumatic cylinder 82R. An end (not shown) of the right connecting rod 80R comprises a piston that slides within the right pneumatic cylinder 82R. The right connecting rod 80R and the right pneumatic cylinder 82R comprise a linear actuator which functions as a resistance assembly for the right lever 40R. As the right connecting rod 80R moves into the right pneumatic cylinder 82R, the right connecting rod 80R pivots with respect to the right upper pivot mount 72R, and the second end of the right pneumatic cylinder 82R pivots with respect to the right lower pivot mount so that the right connecting rod 80R can move freely with respect to the right pneumatic cylinder 82R without binding.

[0040] Within each pneumatic cylinder 82L, 82R, the respective piston divides the cylinder body into two variable volume chambers. At least one of the chambers is a charged chamber that selectively communicates with a compressed air source (shown schematically in FIG. 5) and with the atmosphere so as to provide the desired resistance. The other chamber can be open to the atmosphere; however, in some applications, both chambers can be pressurized (e.g., be of equal pressure), can selectively communicate with the atmosphere and/or can communicate with each other. In the illustrated embodiment, however, one of the chambers communicates with the atmosphere so as not to resist movement of the piston.

[0041] The pneumatic cylinders 82L, 82R may be advantageously constructed from metal or other suitable materials. In one preferred embodiment, the pneumatic cylinders 82L, 82R and the internal pistons comprise a polymer (e.g., plastic) to reduce the manufacturing costs and the weight of the resistance assemblies.

[0042] In the illustrated embodiment, the respective connecting rod 80L, 80R extends through the variable volume chamber open to the atmosphere. The respective connecting rod 80L, 80R moves linearly along a stroke axis as the piston slides within the cylinder bore in the respective pneumatic cylinder 82L, 82R. The stroke lengths of the connecting rods 80L, 80R are sufficient to provide the desired strokes for the upper lever portions 44L, 44R.

[0043] In the illustrated embodiment, the internal chamber proximate the respective second end of each pneumatic cylinder 82L, 82R (e.g., the lower chamber of each cylinder) is pressurized. The lower chamber of the left pneumatic cylinder 82L communicates with at least one left accumulator 90L via a pneumatic tube 92L, as shown more clearly in FIG. 5. Similarly, the lower chamber of the right pneumatic cylinder 82R communicates with at least one right accumulator 90R via a pneumatic tube 92R. The two accu-

mulators 90L, 90R are located behind the seat back portion 24 in the illustrated embodiment and are secured to the frame 12. The pneumatic tubes 92L, 92R function as respective air equalization lines that interconnect the accumulators 90L, 90R with the respective pneumatic cylinders 82L, 82R so as to expand effectively the variable volumes of the lower chambers of the two cylinders. In this manner, the effective air volume of the cylinder is increased, and air pressure thus will not increase as dramatically when the piston is moved.

[0044] Each accumulator 90L, 90R and the respective upper chamber within the pneumatic cylinders 82L, 82R also selectively communicate with the compressed air source (FIG. 5) and with the atmosphere. In the illustrated example, the compressed air source may be, for example, an air compressor, which can be remotely disposed relative to the exercise apparatus. The compressed air source communicates with the upper chambers through a respective inlet valve (shown schematically in FIG. 5). In the illustrated embodiment, the inlet valves for both pneumatic cylinders 82L, 82R are controlled by the left actuator button 66L on the left handgrip 60L when a user manually controls the resistance of the two pneumatic cylinders. The left actuator button 66L is selectively activated by a user to actuate the inlet valves to add air pressure to the lower chamber of each pneumatic cylinder 82L, 82R. The lower chamber is also referred to as the charged side of each cylinder.

[0045] The apparatus 10 further includes a control unit enclosure 100 that houses a control system (described below). The control system within the enclosure 100 communicates with an external computer system (FIG. 5) via a communications cable 102 and an adapter unit 104.

[0046] The apparatus 10 further includes a control and display panel 110 supported on a riser 112 so that the display panel 110 is positioned in front of a user seated in the seat assembly 22.

[0047] As shown in FIG. 4, the display panel comprises a RESISTANCE indicator 120 that displays the total resistance applied to the two handgrips 60L, 60R. The total resistance may be selected by a user by selectively activating the right actuator button 66R to increase the resistance and selectively activating the left actuator button 66L to decrease the resistance. The resistance may also be selected automatically, as described below. The resistance is displayed as the force (in pounds or kilograms) required to move the handgrips 60L, 60R and is calibrated to be equivalent to the force required to move a corresponding stack of conventional weights.

[0048] The display unit 110 also advantageously includes a LEFT REPS indicator 122, a RIGHT REPS indicator 124, a POWER indicator 126, a TARGET REPS indicator 128, a SET indicator 130, a SEAT indicator 132, and an ARM indicator 134. A seat up arrow 136 and a seat down arrow 138 are positioned on the display unit 110 proximate the SEAT indicator 132. An arm up arrow 140 and an arm down arrow 142 are positioned proximate the ARM indicator 134. Each up arrow and each down arrow defines the location of a switch beneath the faceplate of the display unit 110. Each switch can be selectively activated by a user pressing on the respective arrow.

[0049] The display unit 110 includes a data port recess 160 near the lower right corner of the display unit 110. The data

port recess 160 is configured to receive a data key 162. The data key 162 comprises an integrated circuit 164 and a supporting handle 166. The functions of the indicators, the switches, the data port recess and the data key are described in more detail below.

[0050] The control unit enclosure 100 is pneumatically connected to the accumulators 90L, 90R and is thus connected to the charged side of the pneumatic cylinders 82L, 82R. The control unit enclosure is also pneumatically connected to a compressed air source (not shown). Within the control unit enclosure 100, a respective inlet valve (shown schematically in FIG. 5, discussed below) for each accumulator 90L, 90R selectively routes compressed air to the accumulator to increase the air pressure in the accumulator and thus increase the air pressure on the charged side of the corresponding pneumatic cylinder. In preferred embodiments, each inlet valve comprises two inlet valves of varying sizes. A larger inlet valve is selectively activated by a control system (described below) to increase the volume of air in the cylinder rapidly when the resistance level of a pneumatic cylinder is increased. A smaller inlet valve is selectively activated by the control system to increase the volume of air in the cylinder in finer increments when the control system is maintaining a selected resistance level.

[0051] A respective outlet valve (shown schematically in FIG. 5) for each accumulator is selectively opened to release air to the atmosphere in order to decrease the air pressure on the charged side of the cylinder. In the illustrated embodiment, the outlet valves for both pneumatic cylinders 82L, 82R are controlled by the left actuator button 66L on the left handgrip 60L when a user manually controls the resistance of the two pneumatic cylinders. The left actuator button 66L is selectively activated by a user to actuate the outlet valves to reduce the air pressure to the lower chamber of each pneumatic cylinder 82L, 82R.

[0052] A user thus can adjust (e.g., increase or decrease) the air pressure within each resistance assembly by operating the appropriate valves using the right actuator button 66R and the left actuator button 66L.

[0053] Although the right actuator button 66R and the left actuator button 66L could be connected directly to the inlet valves and the outlet valves respectively, in the illustrated embodiment it is preferably that the pressure in the left pneumatic cylinder 82L and the pressure in the right pneumatic cylinder 82R be substantially equal so that the resistance applied to the left handgrip 60L and the resistance applied to the right handgrip 60R are substantially equal. In the illustrated embodiment, this is accomplished by providing a respective actuator signal from each actuator button 66R, 66L to a control system 200 (illustrated in a block diagram in FIG. 5) that is located within the control unit enclosure 100. Although represented as a single control system, in the preferred embodiment, the control system 200 comprises a plurality of microprocessors programmed to perform specific functions, such as real-time measurement and adjustment of air pressures, real-time measurement of positions and computation of velocities, communicating with the user via the display panel, and the like.

[0054] The control system 200 receives the respective actuator signals and determines whether the user is requesting a pressure increase or a pressure decrease. The control system 200 outputs control signals to a left inlet valve 210L

and to a right inlet valve 210R to selectively couple the left accumulator 90L, the right accumulator 90R or both accumulators to a compressed air source 212 to selectively increase the air pressure in one or both accumulators 90L, 90R and the corresponding pneumatic cylinders 82L, 82R. As discussed above, each inlet valve 210L, 210R advantageously comprises a pair of inlet valves. In particular, a large inlet valve in a pair is selectively operated to provide coarse adjustment of the air pressure in the respective pneumatic cylinder. A small inlet valve in a pair is selectively operated to provide fine adjustment of the air pressure in the respective pneumatic cylinder.

[0055] The control system 200 outputs control signals to a left outlet valve 214L and to a right outlet valve 214R to selectively release air from one or both accumulators 90L, 90R to selectively decrease the air pressure in the respective pneumatic cylinders 82L, 82R. The inlet valves and the outlet valves are selectively controlled to achieve the desired pressure change while maintaining substantially equal resistances provided by the two pneumatic cylinders 82L, 82R. The control system 200 accomplishes this by receiving a feedback signal from a left pressure transducer 220L coupled to the left pneumatic cylinder 82L and by receiving a feedback signal from a right pressure transducer 220R coupled to the right pneumatic cylinder 82R. The control system 200 samples the feedback signals periodically (e.g., at a sample rate of 10 times per second in a particular embodiment) and compares the pressure measured in the cylinders with the ambient barometric pressure that is also periodically measured using a barometric pressure transducer 224 in order to determine the actual pressure differential applied to each piston. The control system 200 then adjusts the control signals applied to the inlet valves and outlet valves accordingly.

[0056] FIG. 6 illustrates a block diagram of a system similar to the system in FIG. 5, in which the control system 200 controls a different configuration for the control valves. The other elements of the block diagram in FIG. 6 are similar to the corresponding elements of the block diagram in FIG. 5 and will not be described in detail in connection with FIG. 6.

[0057] In FIG. 6, a first left control valve 610L has a first port 612L coupled to the compressed air source 212. The first left control valve 610L has a second port 614L coupled to the atmosphere. The first left control valve 610L has a third port 616L coupled to a left common galley 620L. The first left control valve 610L is controlled by the control system 200 to be in one of two modes. In a first mode, the first port 612L is coupled to the third port 616L so that the left common galley 620L is coupled to the compressed air source 212. In the second mode, the second port 614L is coupled to the third port 616L so that the left common galley 620L is coupled to the atmosphere.

[0058] The left common galley 620L is coupled to a first port 632L of second left control valve 630L and to a first port 642L of a third left control valve 640L. A second port 634L of the second left control valve 630L is coupled to the left accumulator 90L and to the left pressure transducer 220L via a pneumatic tube 636L. A second port 644L of the third left control valve 640L is coupled to the pneumatic tube 636L via an adjustable orifice 646L. Although shown as a separate element, the adjustable orifice 646L may advantageously be included as part of the third control valve 640L.

[0059] The second left control valve **630L** and the third left control valve **640L** are controlled by the control system **200**. The second left control valve **630L** operates as a high flow valve. The control system **200** activates the second left control valve **630L** to make coarse adjustments to the volume of air in the accumulator **90L** and the pneumatic cylinder **82L**. The third left control valve **640L** operates as a low flow valve. The control system **200** activates the second left control valve **630L** to make fine adjustments to the volume of air in the accumulator **90L** and the pneumatic cylinder **82L** in accordance with the flow rate determined by the adjustable orifice **640L**.

[0060] The control system **200** operates the first left control valve **610L** in combination with the second left control valve **630L** and the third left control valve **640L**. The mode of the first left control valve **610L** determines whether the volume of air in the left accumulator **90L** and the left pneumatic cylinder **82L** is being increased or decreased and the selective activation of the second left control valve **630L** or the third left control valve **640L** determines a rate at which the increase or decrease in volume occurs.

[0061] Similarly, a first right control valve **610R** has a first port **612R** coupled to the compressed air source **212**, a second port **614R** coupled to the atmosphere, and a third port **616R** coupled to a right common galley **620R**. The first right control valve **610R** is controlled by the control system **200** to be in one of two modes as described above for the first left control valve **610L**.

[0062] The volume of air in the right accumulator **90R** and the right pneumatic cylinder are controlled by a second right control valve **630R** having a first port **632R** and a second port **634R** and third right control valve **642R** having a first port **642R**, a second port **644R** and an adjustable orifice **646R**. The right accumulator **90R** and the right pressure transducer **220R** are coupled to the second port **634R** of the second right control valve **630R** and to the adjustable orifice **646R** by a pneumatic tube **636R**.

[0063] The second right control valve **630R** and the third right control valve **640R** are controlled by the control system **200** in combination with the first right control valve **610R** to make coarse adjustments and fine adjustments to the volume of air in the accumulator **90R** and the pneumatic cylinder **82R** as discussed above for the corresponding left components.

[0064] The control system **200** uses the pressure measurements to calculate the resistive force that will be perceived by a user when the handgrips are moved. The calculated resistive force is advantageously displayed as the resistance on the RESISTANCE indicator **120** of the display unit **110** so that a seated user can readily observe the resistance selected by using the left actuator button **66L** and the right actuator button **66R**. As discussed above, the resistance is displayed as the force (in pounds, kilograms or newtons) required to move the handgrips **60L**, **60R** and is calibrated to be equivalent to the force required to move a corresponding stack of conventional weights.

[0065] Once the pressures in the pneumatic cylinders are established by the control system **200**, the user can apply force to the left handgrip **60L** and apply force to the right handgrip **60R** to move the handgrips forward. The forward movement of the handgrips is coupled via the pivoting

action of the left lever **40L** and the right lever **40R** about the left hinge **32L** and the right hinge **32R** to cause the left connecting rod **80L** and the right connecting rod **80R** to move within the left pneumatic cylinder **82L** and the right pneumatic cylinder **82R**. As discussed in U.S. Pat. No. 4,257,593, incorporated by reference herein, the air within the pneumatic cylinders **82L**, **82R** and the accumulators **90L**, **90R** is compressed as the pistons move within the cylinders. The force required to compress the air is coupled through the levers to oppose the movement of the handgrips to provide the user with the effect of lifting weights against gravity but without the inertial effects of conventional weights. It will be appreciated that as the pistons move farther into the respective cylinders, the force required to further compress the air increases; however, the shapes of the upper lever portions **44L**, **44R** are selected such that the user is provided with increasingly more leverage to compensate for the increased air pressure. Thus, the user pushes against substantially the same force throughout each exercise stroke.

[0066] In addition to the mechanical control of the force provided by the shapes of the upper lever portions **44L**, **44R**, the force is also controlled by the control system **200**, which continues to sample the pressure transducers (e.g., at 10 times per second) throughout each exercise stroke and selectively applies control signals to the inlet valves and the outlet valves to maintain the correct pressure in each pneumatic cylinder throughout the exercise stroke. Since the pressure is intended to vary throughout the exercise stroke, the control system **200** must also determine the position of each cylinder throughout the stroke. This is accomplished in the preferred embodiment by precisely measuring the position of each cylinder. In particular, the position of the piston within the left pneumatic cylinder **82L** is determined by a left position transducer **230L**, and the position of the piston within the right pneumatic cylinder **82R** is determined by a right position transducer **230R**. In the illustrated embodiment, each of the position transducers **230L**, **230R** is implemented by a resistive position transducer having a resolution of 1 part in 16,000,000 and having a linearity of better than 1 percent. Each position transducer **230L**, **230R** is sampled 400 times per second to determine the instantaneous position of the piston.

[0067] The control system **200** uses the measured positions of each piston to determine the instantaneous volume of the air in each cylinder. The control system **200** uses the measured barometric pressure and the measured pressures in each cylinder as inputs and solves the universal gas law equation ten times per second to determine whether to add or remove air from each cylinder to maintain the desired resistance at each position in the exercise stroke. The control system **200** also measures the supply pressure provided by the compressor (not shown) via a storage accumulator (not shown) to determine the amount of time to open a respective air inlet valve in order to add the proper amount of air to a cylinder.

[0068] Although the apparatus **10** can be used for exercising the muscles to increase the performance of the muscles, the apparatus **10** is particularly advantageous for implementing the system and method in accordance with aspects of the present invention. In particular, the ability of the control system **200** to accurately measure pressure in the pneumatic cylinders and to accurately measure the position

of the pistons within the pneumatic cylinders enables the apparatus **10** to determine the velocity of movement against the resistive force throughout an exercise stroke and to thereby determine the power of the user throughout an exercise stroke. As described below, by performing a series of such measurements over a range of resistance forces, the user's power as a function of force can be determined. Armed with the information regarding the user's power capabilities, a trainer, a therapist, or the user can tailor exercises to the user's capabilities and the user's goals.

[0069] As discussed above, it is possible to determine average power produced by a muscle or a group of muscles by measuring the distance a force is moved, by measuring the time required to move the force over the measured distance and by measuring or knowing the amount of force being moved. However, such a measurement only provides an average power for an exercise stroke and does not provide any details regarding maximum power during the exercise stroke and does not provide other useful information described below in connection with embodiments in accordance with aspects of the present invention.

[0070] In addition to providing the basic control functions described above to enable the apparatus **10** to be used as an exercise device, the control system **200** is advantageously programmed to enable the apparatus **10** to be used as an evaluation tool.

[0071] As discussed above, the right actuator button **66R** is selectively activated to increase the resistance to the movement of the left handgrip **60L** and the right handgrip **60R**, and the left actuator button **66L** is selectively activated to decrease the resistance to the movement of the two handgrips. Thus, a user is able to increase or decrease the effective "weight" used in an exercise without moving from the seat assembly **22**. When the apparatus **10** is used as an evaluation tool, the left actuator button **66L** and the right actuator button **66R** are activated at the same time by a user in the preferred embodiment. Since there is no reason for a user to attempt to increase the resistance and decrease the resistance at the same time, the concurrent activation of both buttons should not occur during conventional exercise routines. Thus, when the control system **200** receives concurrent signals from both buttons, the control system **200** enters an evaluation routine to perform one embodiment of a method in accordance with one aspect of the present invention. It should be understood that the control system **200** can be caused to initiate and perform the evaluation routine by other means, such as, for example, by activation of a switch dedicated to controlling the operation modes of the control system **200**. For example, the switch may be selectively activated by a key.

[0072] As a failsafe measure, the control system **200** is advantageously programmed to enter the evaluation routine only when the apparatus **10** is activated by an authorized user by applying the data key **162** to the data port recess **160** of the display unit **110** (FIG. 4). The data port recess **160** defines the location of an interface that communicates with the integrated circuit **164** on the data key **162**. In one embodiment, the integrated circuit **164** on the data key **162** comprises an iButton® data device available from Maxim/Dallas Semiconductor Corporation. A compatible interface, also available from Maxim/Dallas Semiconductor Corporation, is positioned in the data port recess **160** of the display

unit **110** to communicate with the integrated circuit **164** when the data key **162** is present. A non-volatile memory within the integrated circuit **164** stores user identification information and advantageously includes historical information related to the user.

[0073] The integrated circuit **164** advantageously includes data specific to each of the apparatuses in a training facility such that when the user applies the data key **162** to the data port recess **160** of a particular apparatus, the data are transferred to the apparatus to cause the apparatus to automatically adjust settings (e.g., resistance levels) and display other settings (e.g., seat and lever arm adjustments) that were last used by the particular user on the particular apparatus. For example, the SEAT indicator **132** is activated by the control system **200** to show a single-digit value corresponding to a conventional height adjustment number proximate the seat bottom portion **26**. Similarly, the ARM indicator **134** is activated by the control system **200** to show a single-digit value corresponding to a selected one of the holes **52L**, **52R** in the arm adjustment selectors **50L**, **50R** that the user has previously determined to be the most suitable. If the user has not previously used a particular apparatus **10**, the two displays may be advantageously initialized to a predetermined value or may be caused to blink to indicate to the user that a value needs to be entered. The user selectively presses on the seat up arrow **136** or the seat down arrow **138** to increment or decrement the associated numerical indication to correspond to the current setting of the seat bottom portion. Similarly, the user selectively presses on the arm up arrow **140** or the arm down arrow **142** to increment or decrement the associated numerical indication to correspond to the current setting of the arm adjustment selectors **SOL**, **50R**. Changes to the numerical indications are stored in the integrated circuit **164** in association with the particular apparatus **10** so that when the user removes the data key **162**, the settings are saved in the integrated circuit **164** and will be displayed to remind the user of the settings the next time the user activates the apparatus **10** by applying the data key **162** to the data port recess **160**.

[0074] In accordance with the method of evaluation described herein, the integrated circuit **164** of the data key **162** identifies the user, and the control system **200** confirms that the user is authorized to perform the evaluation method. Thus, when the user activates both buttons **66L**, **66R**, the control system **200** enters the evaluation method and operates the apparatus **10** in the manner described below in order to obtain data that is processed to evaluate the user's power.

[0075] As further illustrated in FIGS. 5 and 6, the control system **200** is selectively coupled via the communications cable **102** and the adapter **104** to an external computer system **250**. The connection to the external computer system **250** may be a point-to-point connection as illustrated in FIGS. 5 and 6 or the connection may be through a network (hardwired or wireless) wherein the control system **200** is coupled to the network via the adapter **102** and the external computer system **250** is also coupled to the network.

[0076] Routines performed by the control system **200** in accordance with embodiments of the present invention are illustrated in FIGS. 7 and 8. In particular, FIG. 7 illustrates a data gathering routine **700** that is performed repeatedly by the control system as long as power is provided to the

apparatus **10**. For example, in a preferred embodiment, the data gathering routine **700** is performed at a rate of 400 times per second (i.e., every 2.5 milliseconds). In alternative embodiments, the rate can be increased to increase the number of data samples collected during each exercise stroke and thereby increase the resolution of the data or the rate can be decreased to reduce requirements for processing speed and data storage. The preferred rate has been determined to provide adequate data resolution with reasonable requirements for processing speed and data storage. The rate can be determined by a timer coupled to an interrupt system to cause the control system **200** to start the data gathering routine at the beginning of every 2.5-millisecond interval.

[0077] The data gathering routine **700** first enters a decision block **710** wherein the control system **200** interrogates the interface within the data port recess **160** of the display unit **110** to determine whether a valid data key **162** (e.g., a data key having identification information that identifies an authorized user of the apparatus **10**) is positioned in the data port recess **160**. If a data key is not present, the data gathering routine advances to a decision block **720**, wherein the routine determines whether any data were collected while a data key was positioned in the data port recess **160**. For example, the routine examines a data buffer within the control system **200** and determines whether the data buffer is empty. If the data buffer is empty and no data has been collected, the control system returns to the beginning of the routine and waits until the beginning of the next 2.5 millisecond interval before repeating the steps in the decision blocks **710** and **720**. If the data buffer is not empty, then data were collected while the key was inserted, and the collected data need to be transferred in order to clear the data buffer for the next time the apparatus **10** is used. The data transfer is discussed below.

[0078] If the data collecting routine **700** determines in the decision block **710** that a valid data key is present in the data port recess **160**, the routine advances to a decision block **730** and obtains the velocities of the pistons within the pneumatic cylinders **82L**, **82R**. The velocities are advantageously calculated by determining the differences between the current outputs of the position transducers **230L**, **230R** with the previous outputs of the position transducers to determine the amounts of movement during the interval between samples. The calculated velocity for each piston is compared to a minimum velocity to determine whether the user is moving the handgrips at a sufficient rate to indicate that an exercise stroke is in progress.

[0079] If the data collecting routine **700** determines that the minimum velocity has not been achieved by at least one of the pistons, the control system returns to the beginning of the routine and waits until the beginning of the next 2.5 millisecond interval before repeating the step in the decision block **710**. If the data key remains inserted, the routine will again advance to the decision block **730** and compare the velocities of the pistons to the minimum velocity.

[0080] If, in the decision block **730**, the data collecting routine **700** determines that a minimum velocity has been achieved by at least one of the pistons, the routine advances to a data gathering procedure **740** wherein the current positions and the current force are collected and saved for the pistons in the two cylinders. The velocities for the two cylinders are calculated and saved. The current powers being

generated by the two pistons (i.e., force×velocity) are also calculated and saved. In addition, during each sample, the control system **200** determines independently for each piston whether the current calculated velocity for the piston is greater than a previously calculated highest velocity for the piston during the current exercise stroke. If so, the newly calculated velocity is saved as the new peak velocity for the piston. A similar determination is made for the current calculated power for each piston, and a new peak power is saved for a piston if the current calculated power for that piston is greater than the previously saved peak power for that piston.

[0081] After saving the current data and selectively updating the peak velocities and the peak powers in the procedure **740**, the data collecting routine **700** advances to a decision block **750** wherein the control system **200** determines whether the conditions for a complete repetition have been met. For example, the control system may determine from the outputs of the position transducers whether the positions of the pistons are continuing to increase. If the position of at least one of the pistons is continuing to increase, the control system returns to the beginning of the routine and waits until the beginning of the next 2.5 millisecond interval before repeating the steps beginning with the decision block **710**.

[0082] If, in the decision block **750**, the positions of both cylinders are no longer increasing (e.g., the pistons are stationary or the pistons are moving in the opposite direction), the data collecting routine **700** advances to a procedure **760** wherein the control system **200** increments the repetition counter and displays the current repetition counts on the LEFT REPS display **122** and the RIGHT REPS display **124**. The control system transfers the calculated peak velocity, the calculated peak power and the position values (e.g., the positions measured at each sample time) to respective storage locations in a buffer associated with the particular repetition count. Thereafter, the control system resets the peak velocity and the peak power for each piston. The control system returns to the beginning of the routine and waits until the beginning of the next 2.5 millisecond interval before repeating the steps beginning with the decision block **710**.

[0083] If, in the decision block **720**, the data collecting routine **700** determines that data were collected while a valid data key **162** was positioned in the data port recess **160**, then the control system **200** advances to a procedure **770** wherein the data collected while the data key was present are transferred to a download buffer (not shown). The data in the download buffer are available to be downloaded by the external computer system **250**. In particular, the collected data are stored in association with the identification information on the data key **162** so that when the data are downloaded to the external computer system **250**, the data are readily determined to be data produced by a user to whom the data key **162** is assigned. In addition, the procedure **770** resets all the variables (e.g., the repetition counters, the peak velocity, the peak power) and clears the data collection buffers.

[0084] After the data are transferred to the download buffer and the variables are reset, the data collecting routine **700** returns to the beginning of the routine and waits until the beginning of the next 2.5 millisecond interval before repeating the steps described above. Since the data key **162** has

been removed, the transfer of the collected data and the resetting of the variables places the apparatus **10** in condition for the next user to apply a respective data key **162**. Alternatively, the current user may re-insert his or her data key **162** in order to collect additional data.

[0085] The data collecting routine **700** illustrated in FIG. **7** runs as an independent thread in the control system **200** and continues to sample the presence of the key. If the key is present, the routine continues to sample and collect data in the manner described above regardless of whether a user is using the apparatus **10** for exercise or a user is being evaluated, as described below.

[0086] FIG. **8** illustrates a power evaluation routine **800** that enables the apparatus **10** to be used to determine the maximum power generated by a user and to determine the force and velocity at which the maximum power is generated. The routine **800** operates as an independent thread on the control system **200** and automatically increases the resistance applied to the handgrips **60L**, **60R** of the apparatus in a predetermined sequence and at predetermined time intervals in order to perform the evaluation procedure. While the steps in the power evaluation routine **800** are being performed, the above-described data collecting routine **700** continues to run independently to collect the data generated as the user operates the apparatus **10** in response to the changes in resistance imposed by the power evaluation routine **800**.

[0087] The power evaluation routine **800** begins with a decision block **810** in which the control system **200** inputs the signals from the left actuator button **66L** and the right actuator button **66R** to determine whether a user has activated the left actuator button **66L** and the right actuator button **66R** at the same time. The concurrent activation of both actuator buttons **66L**, **66R** does not increase the resistance provided by either the left pneumatic cylinder **82L** or the right pneumatic cylinder **82R**. Rather, the concurrent activation of both actuator buttons signals the control system **200** that the user wants to initiate the power evaluation mode of the apparatus **10**.

[0088] If, in the decision block **810**, the control system **200** determines that at least one of the actuator buttons **66L**, **66R** is not actuated, the power evaluation routine **800** returns to the beginning and enters the decision block **810** again. The control system repeats the decision process in the decision block **810** until the user activates both actuator buttons at the same time.

[0089] When both actuator buttons **66L**, **66R** are activated at the same time, the power evaluation routine **800** advances to a evaluation initialization procedure **820** wherein the control system **200** presets the resistance of each pneumatic cylinder **82L**, **82R** to a preset initial resistance. For example, the initial resistance may be preset to 2.5 pounds per pneumatic cylinder to provide a total resistance of 5 pounds for both cylinders. Alternatively, the initial resistance may be set to a significantly larger value. For example, when evaluating the power of trained athlete, such as a power lifter or a shot putter, the initial resistance may be set to 20 pounds or more.

[0090] In the evaluation initialization procedure **820**, the control system **200** also presets the time between repetitions to a minimum time interval. For example, the minimum time

interval may be 10 seconds or less. In addition, the control system sets a test mode flag within the data buffer into which the collected data are stored by the data collecting routine **700**. For example, the test mode flag is advantageously a particular storage location within the data buffer that is evaluated by the external computer system **250**, as described below in connection with FIG. **10**.

[0091] As the control system **200** is performing the evaluation initialization procedure **820** in the power evaluation routine **800**, the control system advantageously blinks the LEFT REPS display **122** and the RIGHT REPS display **124** as an indication to the user that the user should wait before pushing on the handgrips. After the evaluation initialization procedure **820** is completed, the control system discontinues blinking the two displays and outputs signals to display the values of the repetition counters, which were set to 0 by the data collecting routine **700** in response to the removal of the data key **162** by the previous user.

[0092] When the LEFT REPS display **122** and the RIGHT REPS display **124** stop blinking with values of 0 displayed on each display, the user applies maximum force to the handgrips **60L**, **60R** to move the handgrips at the maximum speed the user can achieve. The low inertia provided by each of the pneumatic cylinders **82L**, **82R** enables the user to reach a high speed quickly. The low inertia also enables the user to maintain a high speed throughout the exercise stroke since the user does not have to worry about the inertia of a conventional weight stack continuing to pull the user's arms forward even after the user stops applying force. The user continues to push the handgrips forward to the limit of the user's reach. The user then pulls the handgrips back to the initial starting positions of each handgrip. As discussed above, when the decision block **760** in the data collecting routine **700** detects the completion of the repetitions by both handgrips, the procedure **720** increments the repetition counters accordingly.

[0093] After presetting the initial resistance and the minimum time interval in the procedure **820**, the power evaluation routine **800** advances to a decision block **830** wherein the control system **200** monitors the repetition counters to determine whether the repetition counters have been incremented by the data collecting routine **700**, as described above. Since the two handgrips **60L**, **60R** are operated independently, the user may not complete the exercise stroke at the same time for both handgrips. If at least one of the left repetition counter or the right repetition counter has not been incremented, the power evaluation procedure returns to the decision block **830** and continues to monitor the two repetition counters.

[0094] When the power evaluation procedure **800** determines in the decision block **830** that both the left repetition counter and the right repetition counter have been incremented by the procedure **760** in the data collecting routine **700**, the power evaluation routine advances to an update procedure **840**. In the update procedure **840**, the control system **200** outputs commands to the left control valves **610L**, **630L**, **640L** and outputs commands to the right control valves **610R**, **630R**, **640R** while monitoring the left pressure transducer **220L** and the right pressure transducer **220R**. The volumes of air in the pneumatic cylinders **82L**, **82R** and the respective accumulators **90L**, **90R** are selectively increased or decreased to cause the resistances of each

pneumatic cylinder **82L**, **82R** to be increased to the next incremental resistance level. The increments can be selected in accordance with the strength of users. For example, in an embodiment intended to evaluate non-athletic users, the total resistance level provided by both pneumatic cylinders may be increased in 5-pound increments. The resistance level may be increased by incremental amounts less than 5 pounds for weak users (e.g., users in rehabilitation). For athletic users, the resistance level may be advantageously increased by larger amounts, such as, for example, 20-pound increments. Other increments between 5 pounds and 20 pounds and increments greater than 20 pounds can also be used for particular applications. For example, as discussed below, the amount of the increments can be selected in accordance with a desired maximum resistance level and a desired number of strokes to reach the maximum resistance level.

[0095] The initial force and the amount by which the force is incremented are advantageously selected to increase the force to a level where the user can no longer complete twenty exercise strokes. Thus, in the two examples, the non-athletic user may be expected to not be able to complete a twentieth repetition at approximately 100 pounds, and the athletic user may be expected to not be able to complete a repetition at 400 pounds. In one particularly advantageous embodiment, the user is provided with an initial starting force and the decrease in velocity in response to the first few (e.g., four) increments of force are used to predict the likely maximum force the user can move. The subsequent increments of the force are selected to exceed the likely maximum force for the user at approximately 20 repetitions. Twenty repetitions are advantageously selected in the illustrate embodiment to provide a sufficient number of data points within a reasonable amount of time to complete the evaluation procedure.

[0096] In other embodiments, the maximum resistance force can be set by the user using the left actuator button **66L** or the right actuator button **66R**. For example, the maximum resistance may be entered when the apparatus is being used to periodically test an athlete who established his or her maximum resistance capability in one or more previous evaluation sessions or by using other equipment. In such embodiments, the incremental increases in resistance may be calculated in accordance with a predetermined number of exercise strokes (e.g., 20) to reach the maximum resistance entered by the user. In a further modification of such an embodiment, the user is prompted to enter a number of exercise strokes desired to reach the maximum resistance previously entered. For example, this modification enables a user to enter a smaller number of exercise strokes in order to more quickly test for improvements in power in comparison to previous evaluation sessions. This modification is advantageous when a large number of users need to be periodically evaluated (e.g., the players on a football team, a baseball team, or the like) and it is desirable to evaluate each user quickly.

[0097] In another modification, the user is prompted to enter an initial resistance force and to then enter an incremental resistance force. This modification enables the user to focus the evaluation session on resistance forces in a range where the user is seeking to improve his or her power generation. For example, a baseball player may concentrate on developing more power in a lower range of forces, a shot

putter may concentrate on developing higher speeds at a mid-range of forces, and a power lifter may concentrate on developing more power at a higher range of forces. In each case, the user attempts to achieve greater velocities while moving against the resistances in the selected range of forces.

[0098] In addition to incrementing the force to the next level in the procedure **840**, the control system **200** also calculates a time interval before the start of the next repetition. At the lower resistance levels, a user's muscles do not require much rest after an exercise stroke before being ready to perform the next exercise stroke at the next higher resistance level. As the resistance level increases, the amount of energy expended during each exercise stroke becomes larger. In addition, the cumulative energy expended in each exercise stroke increases at a higher rate. The procedure **840** provides an increasing time interval between exercise strokes to provide more recovery time for the user's muscles between exercise strokes to provide a more accurate indication of the user's performance at the higher resistance levels.

[0099] After setting the time interval in the procedure **840**, the power evaluation routine **800** advances to a decision block **850** wherein the control system **200** determines whether there is less than 10 seconds remaining in the time interval. If more than 10 seconds remain, the power evaluation routine returns to the decision block **850** and continues to evaluate the time remaining in the time interval.

[0100] When the power evaluation routine **800** determines in the decision block **850** that less than 10 seconds are remaining in the time interval, the power evaluation routine advances to a procedure **860** wherein the control system **200** displays the seconds remaining in the interval on the SET display **130** on the display unit **110**. The control system continues to display the remaining seconds in the time interval as the seconds decrement to 0. When the seconds decrement to 0, the power evaluation routine returns to the decision block **830** and waits for the user to complete an exercise repetition against the increased resistance.

[0101] The power evaluation routine **800** repeats the operations in the decision block **830**, the procedure **840**, the decision block **850** and the procedure **860** as long as the data key **162** is positioned in the data port recess **160**. At the same time, the data collecting routine **700**, operating as an independent thread, continues to collect data as the user performs the exercise strokes. When the user is no longer able to complete an exercise stroke after the resistance is increased, the user removes the data key **162** to conclude the data collecting process performed by the data collecting routine **700**. In addition, removal of the data key **162** causes the control system **200** to terminate the current power evaluation routine **800** and return to the decision block **810** at the beginning of the power evaluation routine **800** to wait for both actuators **66R**, **66L** to be concurrently activated to start a new power evaluation routine. In other advantageous embodiments, the data collecting process concludes when the data collecting routine **700** determines that a sufficient amount of data has been collected to evaluate the user's power regardless of whether the user is able to complete more exercise strokes or exercise strokes at greater resistance values. For example, as discussed above, the data collecting process can be advantageously concluded when

the user has performed a predetermined number of exercise strokes or when the resistance has been incremented to a predetermined resistance level.

[0102] As discussed above, as the exercise stroke is occurring, the control system 200 continues to monitor the pressures within the pneumatic cylinders 82L, 82R and adjusts the pressures as required to maintain the selected force on the handgrips close to the desired force throughout the exercise stroke.

[0103] In a variation of the above-described power evaluation routine 800, the procedure 860 is advantageously modified to provide the user with only a single indication to start an exercise stroke. By not providing a countdown or other warning prior to the next exercise stroke, the control system 200 can determine a user's reaction time by measuring the time from the appearance of the indication to the initial movement of the exercise stroke.

[0104] As discussed above, after the data key 162 is removed, the data collecting routine 700 transfers the collected data to a buffer that is accessible by the external computer system 250. For example, the control system 200 advantageously includes a network interface that couples to a network via the cable 102 and the adapter 104 in order to communicate with the external computer system 250, which is also coupled to the network.

[0105] As illustrated by a polling routine in FIG. 9, the external computer system 250 systematically interrogates each apparatus 10 connected to the common network. In particular, in a decision block 910 the external computer system 250 evaluates the response received from a first apparatus 10 on the network and determines whether the response indicates that the apparatus 10 has data available. As discussed above, the apparatus 10 indicates whether collected data were transferred to the transfer buffer by the procedure 770 in FIG. 7 that have not yet been transferred (i.e., downloaded) to the external computer system 250 in response to a prior interrogation. If no data are available to be transferred, the external computer system addresses and interrogates the next apparatus 10 on the network in a procedure 920 and then returns to the decision block 910 to determine whether data are available from the next apparatus to be downloaded.

[0106] If the external computer system determines in the decision block 910 that data are available to be downloaded from the currently addressed apparatus 10, the external computer system 250 advances to a procedure 930 wherein the external computer system 250 downloads the collected data from the apparatus 10 and saves the collected data in a disk file. For example, in the illustrated embodiment, the collected data are saved in a comma separated value (CSV) format, which is a data exchange format that is compatible with many spreadsheet programs and other data evaluation programs. After storing the data downloaded from a currently addressed apparatus, the external computer system addresses and interrogates the next apparatus 10 in a procedure 940 and then returns to the decision block 910 to determine whether data are available from the next apparatus to be downloaded.

[0107] The routine 900 illustrated in FIG. 9 is advantageous for an exercise or evaluation facility having a large number of apparatuses that collect data as users perform

exercise routines or as users are evaluated. The external computer system stores the collected data in association with the identification information from the data key 162 that enabled the collection of the data so that the data can later be identified as being generated by a particular user.

[0108] FIG. 10 illustrates a data graphing routine 1000 that is selectively performed by the external computer system 250 in response to a request to view the data collected by the apparatus 10 and transferred to the computer system 250. In a procedure 1010, the data graphing routine 1000 opens a data file requested by a user. For example, the data file may advantageously be identified by a selected combination of date, time, machine number and data key identification.

[0109] After opening the requested data file, the data graphing routine 1000 advances to a decision block 1020 wherein the external computer system 250 analyzes the exercise machine information included as part of the data file to determine whether support is provided for translating the collected data to "at the handle data." In particular, in the illustrated embodiment, the position transducers 230L, 230R measure the movement of the pistons within the respective pneumatic cylinders 82L, 82R. Similarly, the pressure transducers 220L, 220R measure the pressure within the respective pneumatic cylinders. Thus, the data collected by the data collecting routine 700 of FIG. 7 represents the velocity and the force at the pneumatic cylinders. Since the pistons of the pneumatic cylinders are coupled to the handgrips 60L, 60R (i.e., the handles) via the linkages provided by the connecting rods 80L, 80R, and the levers 40L, 40R, the velocities and forces at the pneumatic cylinders are different from the velocities and forces at the handles. The velocities and forces at the handles are computed by applying known trigonometric relationships to translate the forces and movements at the cylinders at respective upper ends of the levers 40L, 40R to the forces and movements at the handles at the lower ends of the levers. Since the angles of the connecting rods 80L, 80R with respect to the upper ends of the levers change as the connecting rods are pushed further into the respective cylinders, the translations must be computed for each position.

[0110] If the information required to translate the piston position and force data to handle position and force data is available for the particular exercise machine that collected the data being graphed, the graphing routine 1000 advances from the decision block 1020 to a procedure 1030 wherein the computer system 250 translates the collected "at the cylinder" to "at the handle" data. The translated data are then graphed in either metric (SI) units or imperial units as selected by the operator.

[0111] If the information required to translate the piston position and force data to handle position and force data is not available for the particular exercise machine that collected the data being graphed, the graphing routine 1000 advances from the decision block 1020 to a procedure 1040 wherein the computer system 250 graphs the data as "at the cylinder" values in metric (SI) units.

[0112] The data graphed by the computer system 250 in the procedure 1030 or in the procedure 1040 comprises the conventional data that is collected by the data collecting routine 700 for each exercise stroke. In particular, the graphs show the position, the calculated velocity and the calculated power as functions of time for each exercise stroke.

[0113] After completing either the procedure 1030 or the procedure 1040, the graphing routine 1000 advances to a decision block 1050 wherein the computer system 250 analyzes the data received from the exercise machine to determine whether the test mode flag was set in the collected data, as discussed above in connection with the procedure 820 in FIG. 8. If the test mode flag is not set, the graphing procedure is done for the currently accessed data file.

[0114] If the test mode flag is set in the collected data, the graphing procedure 1000 advances from the decision block 1050 to a procedure 1060 wherein the computer system 250 generates and displays power evaluation graphs produced in accordance with the power evaluation routine 800 of FIG. 8. In particular, rather than simply graphing the position, velocity and power as a function of time, the procedure 1060 graphs the peak velocity and the peak power for each handgrip as a function of force as illustrated in FIG. 11.

[0115] In FIG. 11, the scale along the horizontal axis represents the resistance applied to each handle during a particular exercise stroke, the scale along the left vertical axis represents the peak velocity achieved during a particular exercise stroke, and the scale along the right vertical axis represents the peak power achieved during each exercise stroke. In FIG. 11, the force is presented as newtons, the velocity is presented as meters per second, and the power is presented as watts. It should be readily understood that the force, velocity and power in FIG. 11 can also be advantageously presented in imperial units of pounds, inches per second and watts, respectively. In FIG. 11, separate plots of velocity and power are provided for each arm, and the force in the horizontal axis is the force per arm rather than the total force.

[0116] A first graph 1110 is a plot of maximum velocity versus force for the left arm. A second graph 1120 is a plot of maximum velocity versus force for the right arm. A third graph 1130 is a plot of maximum power versus force for the left arm. A fourth graph 1140 is a plot of maximum power versus force for the right arm. Although the graphs in FIG. 11 are shown as continuous graphs, it should be understood that the graphs represent plots of discrete data points. The data points are interconnected with straight lines to enable the data to be more easily visualized. The graphs in FIG. 11 are based on data measured in increments of 10 pounds (approximately 44 newtons) in the total force applied to both arms. Thus, the data represent increments of 5 pounds (approximately 22 newtons) in the force applied to each arm.

[0117] In general, the velocity graphs 1110, 1120 show that the maximum velocities occur at very low forces, and that the maximum velocities generally decrease steadily as the resistance level increases.

[0118] In general, the power graphs 1130, 1140 start at relatively low values at the lower resistance levels. Since the amount of force is very low, the power is low. As the resistance level increases, the power increases generally steadily until the power reaches a maximum magnitude. As the resistance level continues to increase, the velocity continues to decrease and the power also decreases.

[0119] From the graphs in FIG. 11, it can be seen that the power reaches a maximum magnitude for different forces and velocities for the user's left arm and the user's right arm for the illustrated measurement sequence. For example, the graphs 1110 and 1120 indicate that at each resistance level, the left arm generally has a greater velocity than the velocity of the right arm. Thus, the left arm generally has more power

at most resistance levels, as indicated by the graphs 1130 and 1140. Of course, the graphs of FIG. 11 will vary in accordance with the velocities and powers generated by the two arms of different users.

[0120] 81 Assuming that the information in the graphs of FIG. 11 remains consistent over multiple measurements (e.g., that the particular user consistently moves the handgrips at the highest velocities for each increment of resistance level), an athletic trainer or a therapist may use the information in the graphs as a basis for determining that the particular user should focus on training at heavier weights (e.g., at resistances above approximately 240 newtons per arm in order to increase the power of both arms at higher resistances.

[0121] Subsequent measurements of power after recommended exercises can determine whether the results of the exercises exhibit a trend in the correct direction (e.g., increasing power in the ranges that were initially weaker).

[0122] The graphs of FIG. 11 also provide additional information. As discussed above, certain athletic activities, such as competitive weight lifting, require maximum power at high levels of force while maintaining a moderate velocity at those levels. On the other hand, other athletic activities, such as for example, throwing baseballs, require maximum power at much higher velocities without requiring high levels of force. In between, activities, such as putting the shot, require maximum power at higher levels of force than throwing baseballs while maintaining a relatively high velocity. The apparatus and method described herein can be advantageously used to gather data to develop graphs of the power of successful athletes and persons in other professions requiring physical ability to determine the resistance levels where such athletes and other persons produce the most power. This information can be advantageously used to evaluate aspiring athletes and other persons to determine how they compare to the anticipated power requirements for their activities. Armed with the information thus obtained, the person can develop a training program to properly condition the muscles to obtain the desired results.

[0123] Other population profiles can also be developed for other groups of persons (e.g., persons in particular age ranges or persons having other demographic characteristics). The power of a subject being evaluated can be compared with the norms of other persons in his or her population group to provide a relative measure of the power of the subject.

[0124] It should be understood that the foregoing description of a chest press apparatus is only one example of a measurement apparatus that can implement the system and method in accordance with aspects of the present invention. For example, one skilled in the art will appreciate that the foregoing features can be advantageously incorporated into a leg conditioning apparatus to enable the power of the legs to be measured to determine the velocity and resistance level where a subject develops the maximum power. After determining the velocity and resistance level for maximum power, a suitable conditioning program can be developed to increase the velocity and the strength to achieve a desired result.

[0125] Although described above with respect to athletic ability, it should be understood that the apparatus and method in accordance with aspects of the embodiments of the present invention can be advantageously used in other environments. For example, one problem encountered by a

significant portion of an aging population is loss of strength and mobility. Failure to develop and maintain an adequate physical condition while younger becomes a far greater problem as the muscles deteriorate and weaken. It has been shown that strengthening exercises are beneficial to the overall health of an aging individual. However, as discussed above, measurement of strength alone is not sufficient in most cases to properly determine a person's physical ability. The above-described apparatus and method can be advantageously used to determine the resistance level and velocity where a person has the greatest power. A conditioning program can then be developed to improve the person's overall power rather than simply increasing strength or increasing speed. More particularly, by starting where the person has the most power, the conditioning program can start at a force and velocity where the person is most likely to be able to complete an exercise routine such that the person will also develop the confidence required to continue with the conditioning program. Other low-inertia exercise apparatuses that can be automatically controlled to selectively increment the resistance between each successive exercise stroke can also be advantageously used. For example, apparatuses using electromagnetic resistance devices, apparatuses using hydraulic resistance devices, or the like, may be used.

[0126] The invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is therefore indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within that scope.

What is claimed is:

1. A method of evaluating the power of a muscle group, comprising:
 - initializing a resistance element to a first resistance level;
 - moving an engagement assembly coupled to the resistance element at a highest achievable velocity through an exercise stroke;
 - measuring a representative velocity at which the engagement assembly is moved through the exercise stroke and collecting data responsive to the representative velocity;
 - increasing the resistance level of the resistance element;
 - repeating the acts of moving, measuring and increasing until sufficient data are collected;
 - calculating power for each exercise stroke based on the resistance level for each exercise stroke and the representative velocity for each exercise stroke; and
 - determining a maximum power.
2. The method as defined in claim 1, further including determining a velocity and a resistance level where the maximum power is produced.
3. The method as defined in claim 1, wherein the resistance element is a pneumatic cylinder in which the engagement assembly causes a piston within the pneumatic cylinder to move against air pressure in the pneumatic cylinder.
4. The method as defined in claim 1, wherein the engagement assembly is configured as a chest press, and wherein a first handgrip is provided for a left hand of a subject and a second handgrip is provided for a right hand of a subject,

each handgrip being coupled to a respective resistance element, the act of measuring being performed independently for each handgrip to provide an independent power measurement for each arm of the subject.

5. The method as defined in claim 1, wherein the time between the act of measuring selectively increases as the resistance level increases to enable the muscle group to rest between successive acts of moving the engagement assembly.

6. The method as defined in claim 1, wherein the velocity is determined by periodically measuring a position of a piston in a pneumatic cylinder, and the velocity is calculated based on the distance moved during a known time interval.

7. The method as defined in claim 1, wherein sufficient data are collected when the resistance level is sufficient to preclude moving the engagement assembly through a complete exercise stroke.

8. The method as defined in claim 1, wherein sufficient data are collected when the resistance level is incremented to a predetermined level.

9. The method as defined in claim 1, wherein sufficient data are collected when a predetermined number of exercise strokes are completed.

10. A system for evaluating the power of a muscle group, comprising:

a variable resistance element automatically adjustable to produce a sequence of increasing resistance levels;

an engagement assembly coupled to the resistance element to move against the resistance provided by the resistance element during an exercise stroke;

a position transducer sampled at predetermined time intervals to enable determination of a representative velocity at which the engagement assembly is moved through the exercise stroke at a highest achievable velocity for the resistance level coupled to the engagement assembly; and

a power calculation system that calculates the power for each exercise stroke based on the resistance level for each exercise stroke and the representative velocity for each exercise stroke, the power calculation system determining a maximum power and determining a velocity and a resistance level where the maximum power is produced.

11. The system as defined in claim 10, wherein the resistance element is a pneumatic cylinder in which the engagement assembly causes a piston within the pneumatic cylinder to move against air pressure in the pneumatic cylinder.

12. The system as defined in claim 10, wherein:

the engagement assembly is configured as a chest press having a first handgrip for a left hand of a subject and having a second handgrip for a right hand of the subject;

the variable resistance element comprises a first resistance element coupled to the first handgrip and a second resistance element coupled to the second handgrip, each resistance element including a respective position transducer; and

the power calculation system calculates the power independently for each arm of the subject.



US 20110224665A1

(19) **United States**

(12) **Patent Application Publication**

Crosby et al.

(10) **Pub. No.: US 2011/0224665 A1**

(43) **Pub. Date:** Sep. 15, 2011

(54) **MODULAR STIMULATOR FOR TREATMENT OF BACK PAIN, IMPLANTABLE RF ABLATION SYSTEM AND METHODS OF USE**

(76) Inventors: **Peter Andrew Crosby**, Minneapolis, MN (US); **Dan Sachs**, Minneapolis, MN (US); **Prashant Brijmohansingh Rawat**, Blaine, MN (US); **Jason Alan Shiroff**, Edina, MN (US); **Johannes Petrus Heemels**, Keerbergen (BE)

(21) Appl. No.: **13/045,421**

(22) Filed: **Mar. 10, 2011**

Related U.S. Application Data

(60) Provisional application No. 61/339,957, filed on Mar. 11, 2010.

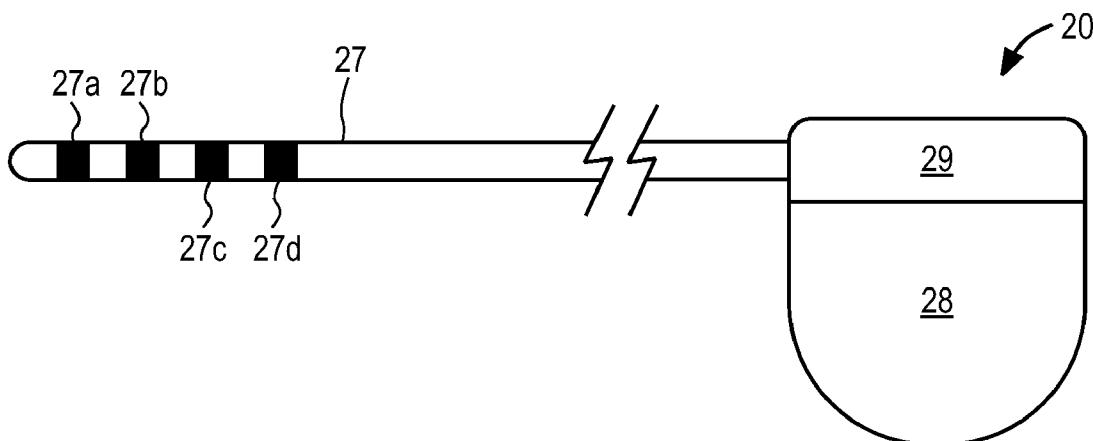
Publication Classification

(51) **Int. Cl.**
A61B 18/18 (2006.01)
A61N 1/36 (2006.01)

(52) **U.S. Cl.** **606/33; 607/46**

(57) **ABSTRACT**

Apparatus and methods for treating back pain are provided, in which an implantable stimulator is configured to communicate with an external control system, the implantable stimulator providing a neuromuscular electrical stimulation therapy designed to cause muscle contraction to rehabilitate the muscle, restore neural drive and restore spinal stability; the implantable stimulator further including one or more of a number of additional therapeutic modalities, including a module that provides analgesic stimulation; a module that monitors muscle performance and adjusts the muscle stimulation regime; and/or a module that provides longer term pain relief by selectively and repeatedly ablating nerve fibers. In an alternative embodiment, a standalone implantable RF ablation system is described.



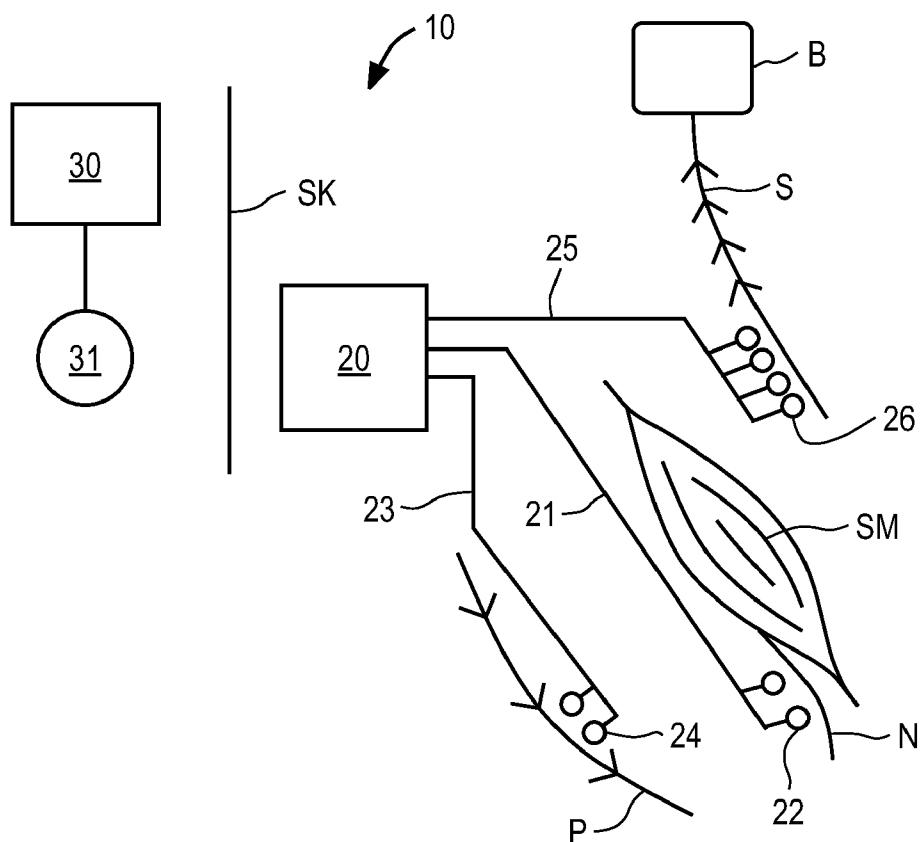


FIG. 1

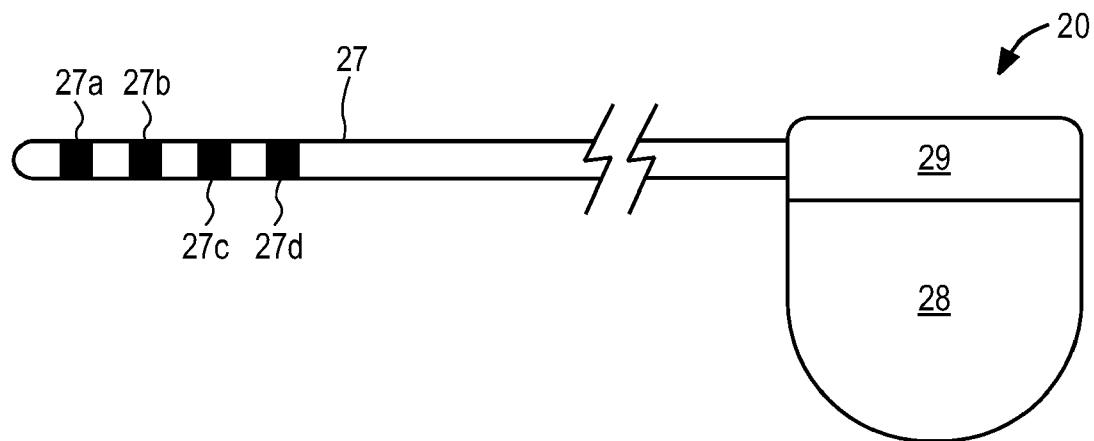


FIG. 2

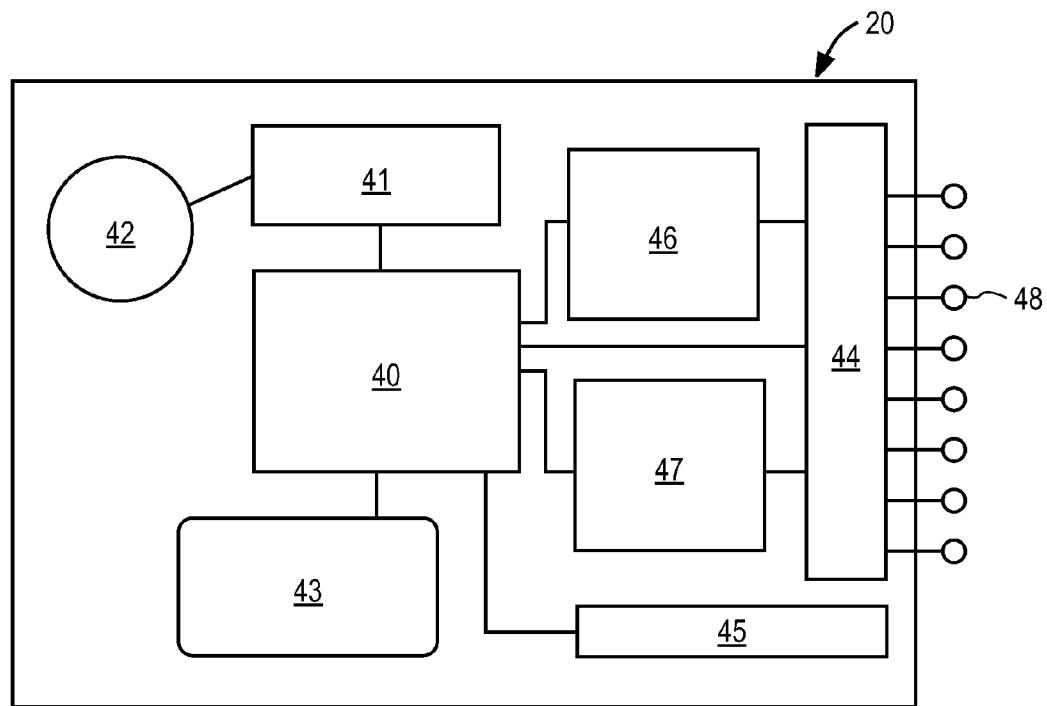


FIG. 3

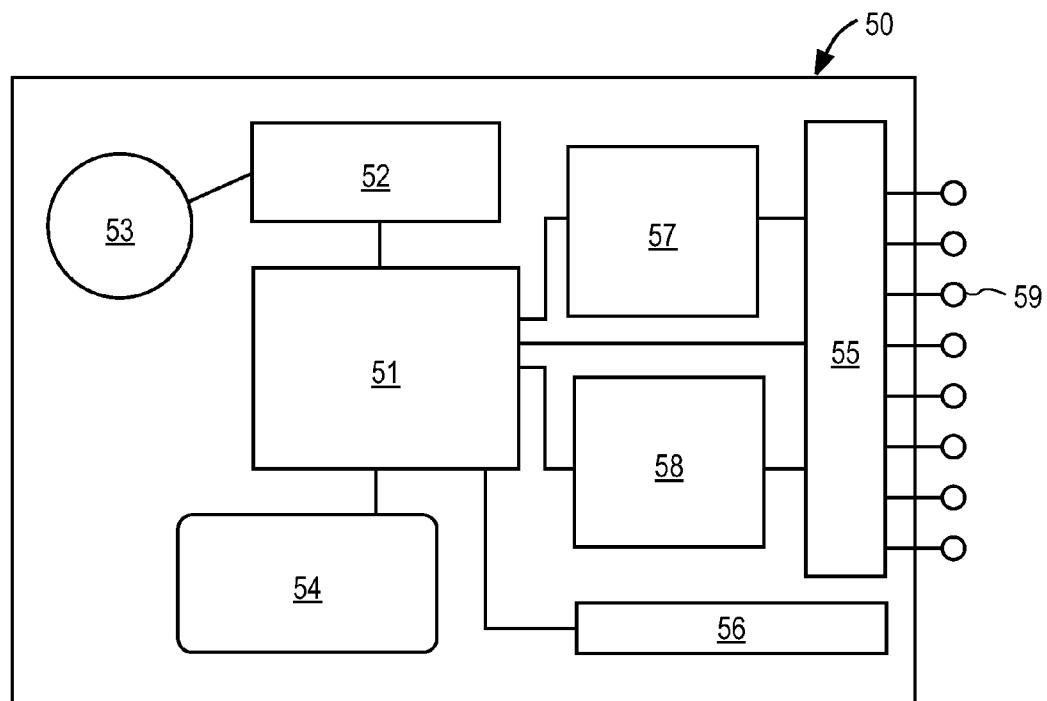


FIG. 4

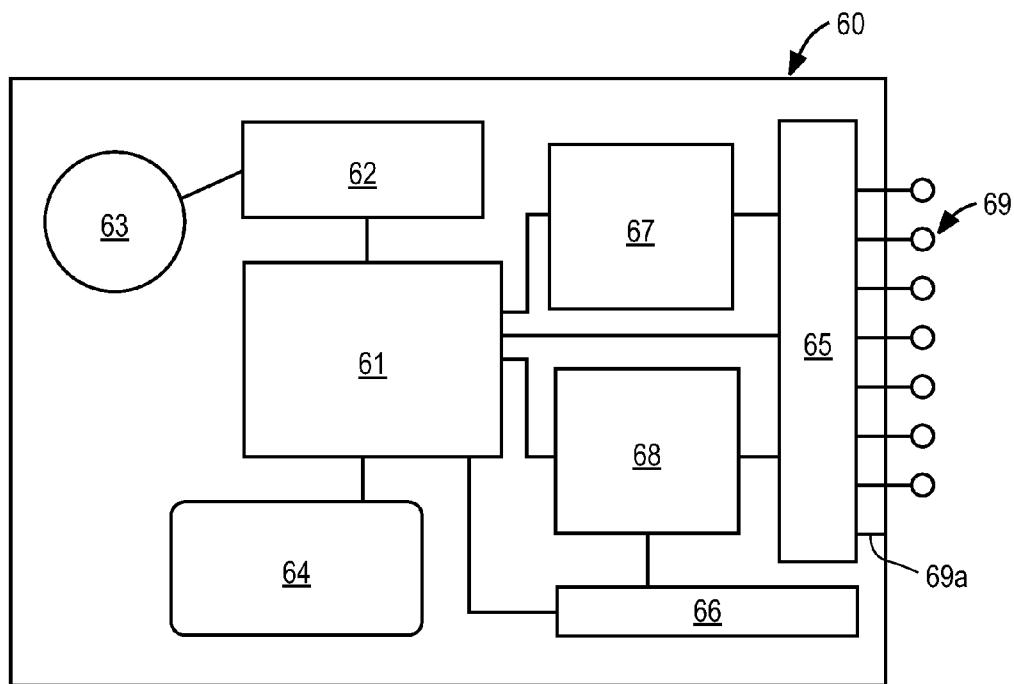


FIG. 5

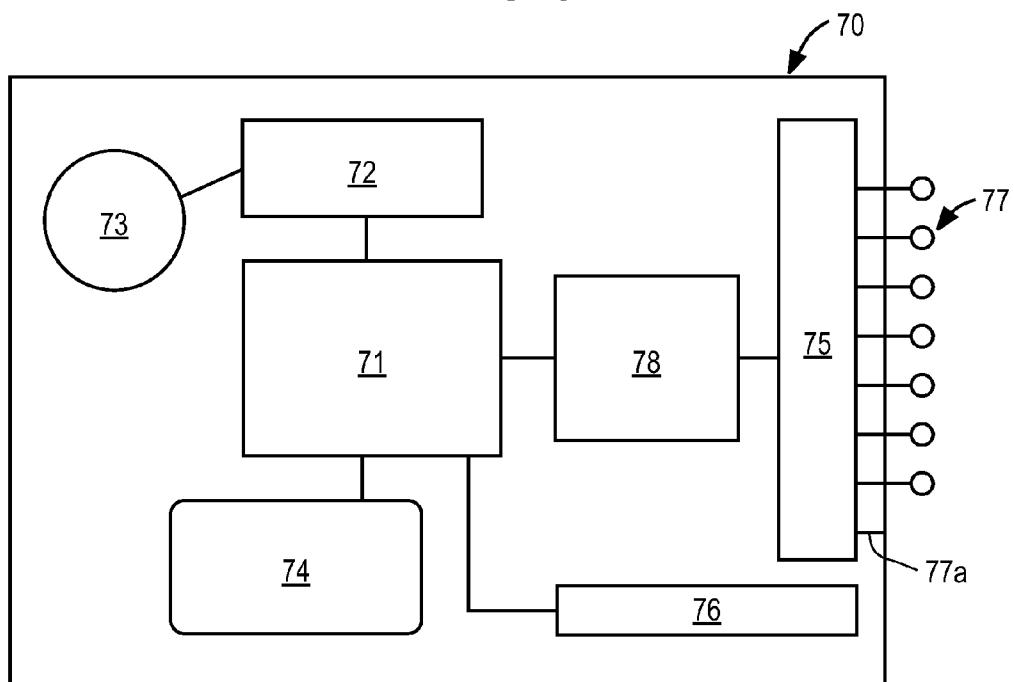


FIG. 6

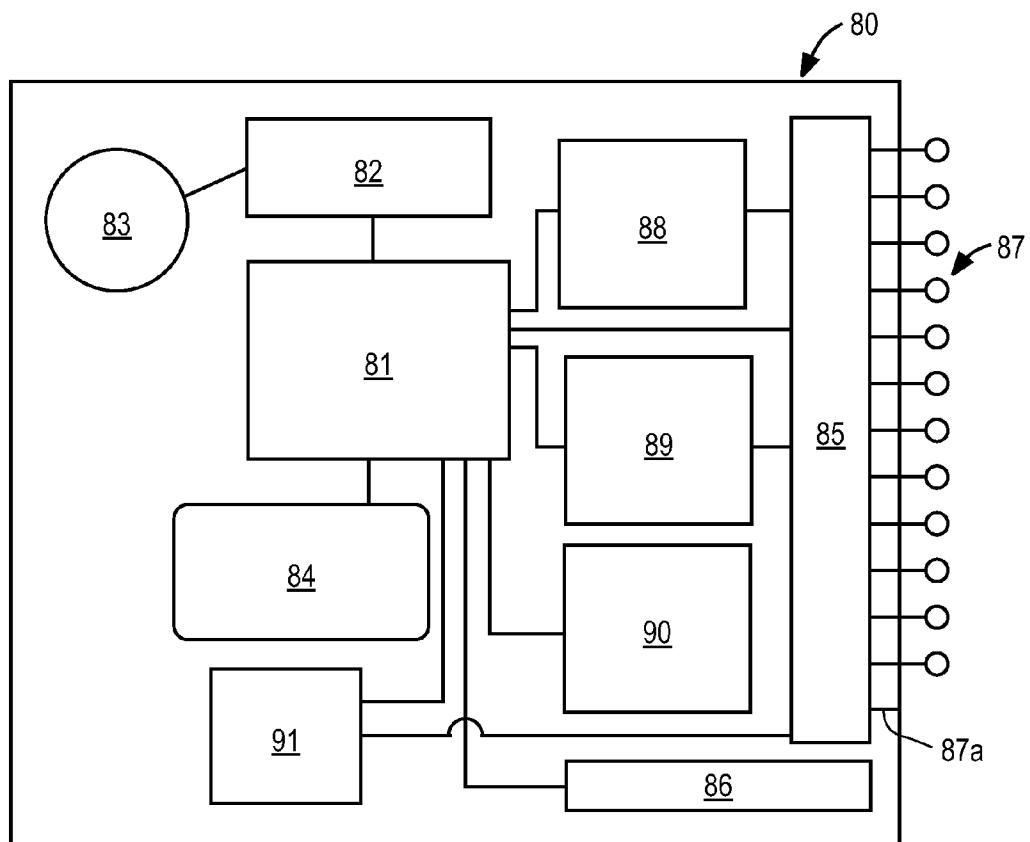


FIG. 7

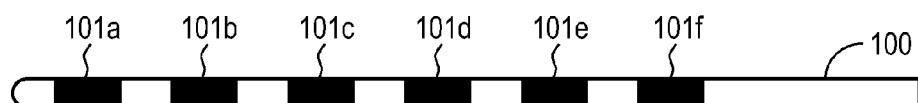


FIG. 8A

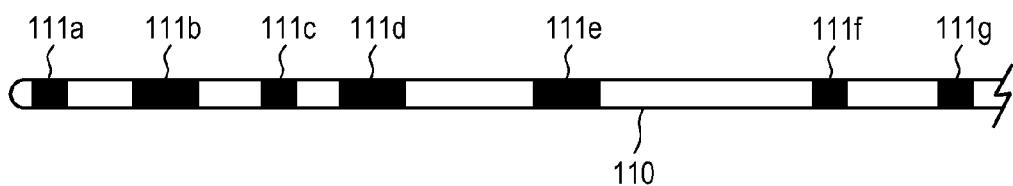


FIG. 8B

**MODULAR STIMULATOR FOR TREATMENT
OF BACK PAIN, IMPLANTABLE RF
ABLATION SYSTEM AND METHODS OF USE****REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of priority of U.S. provisional application Ser. No. 61/339,957, filed Mar. 11, 2010.

FIELD OF THE INVENTION

[0002] This application relates to apparatus and methods for treating back pain by combining circuitry for providing neuro-muscular electrical stimulation (NMES) therapy with circuitry for providing analgesic stimulation, performance monitoring and feedback, and/or selective ablation.

BACKGROUND OF THE INVENTION

[0003] The human back is a complicated structure including bones, muscles, ligaments, tendons, nerves and other structures. The spinal column consists of interleaved vertebral bodies and intervertebral discs. These joints are capable of motion in several planes including flexion-extension, lateral bending, axial rotation, longitudinal axial distraction-compression, anterior-posterior sagittal translation, and left-right horizontal translation. The spine provides connection points for a complex collection of muscles that are subject to both voluntary and involuntary control.

[0004] Muscles provide mechanical stability to the spinal column. Cross sectional images of the spine demonstrate that the total area of the cross sections of the muscles surrounding the spinal column is much larger than the spinal column itself. Additionally, the muscles have much larger lever arms than those of the intervertebral disc and ligaments. The motor control system sends signals down nerves to activate the muscles of the back in concert to maintain spine stability.

[0005] The multifidus is the largest and most medial of the lumbar back muscles. It consists of a repeating series of fascicles which stem from the laminae and spinous processes of the vertebrae, and exhibit a substantially similar pattern of attachments caudally. These fascicles are arranged in five overlapping groups such that each of the five lumbar vertebrae gives rise to one of these groups. At each segmental level, a fascicle arises from the base and caudolateral edge of the spinous process, and several fascicles arise, by way of a common tendon, from the caudal tip of the spinous process. Although confluent with one another at their origin, the fascicles in each group diverge caudally to assume separate attachments to the mamillary processes, the iliac crest, and the sacrum. Some of the deep fibers of the fascicles which attach to the mamillary processes attach to the capsules of the facet joints next to the mamillary processes. All the fascicles arriving from the spinous process of a given vertebra are innervated by the medial branch of the dorsal ramus that issues from below that vertebra.

[0006] Normally, load transmission in the spinal column is painless, with the muscles acting in concert with the ligaments and bones preventing excessive relative movements of the structures. The neutral zone is the range of intervertebral motion, measured from a neutral position, within which the spinal motion is produced with a minimal internal resistance. Over time, dysfunction of the spinal stabilization system can lead to instability and abnormal movement of the spine, resulting in overloading of structures when the spine moves

beyond its neutral zone. High loads can lead to inflammation, disc degeneration, ligament damage, facet joint degeneration, and muscle fatigue, all of which can result in pain.

[0007] For patients believed to have back pain due to instability, clinicians first offer a group of therapies that attempts to minimize the abnormal range of motion that leads to the pain. If this group of therapies does not work, then the next group of therapies aims to block the pain produced by the abnormal range of motion.

[0008] Common conservative methods of attempting to reduce abnormal motion aim to improve muscle strength and control and include core abdominal exercises, use of a stability ball, and Pilates. If conservative methods of preventing abnormal movement are ineffective, surgical approaches may be used.

[0009] Spinal fusion is the standard surgical treatment for chronic back pain. One or more vertebrae are surgically fused together to prevent relative motion. Following fusion, motion is reduced across the vertebral motion segment. Dynamic stabilization implants are intended to reduce abnormal motion and load transmission of a spinal motion segment, without fusion. Total disc replacement and artificial nucleus prostheses also aim to improve spine stability and load transmission while preserving motion.

[0010] If pain persists after physical therapy or surgical intervention to prevent the abnormal motion that leads to pain, few options are available for relief.

[0011] One option is a technique referred to as "RF rhizotomy", in which radio frequency ("RF") energy is used to ablate the medial branch of the dorsal ramus that contains the afferent fibers responsible for transmitting pain signals from the facet joint. There are several devices available for performing this treatment, such as those offered by Baylis Medical Inc. (Montreal, Canada). While this technique can be effective, it provides only short term relief as nerve fibers may regenerate over time, and generally the procedure must be repeated approximately every six months to maintain effective pain control. The electrical parameters for RF ablation of nerves differ amongst various suppliers.

[0012] Another option for pain relief is Transcutaneous Electrical Nerve Stimulation (TENS). This technology provides low energy electrical signals delivered via externally applied skin pad electrodes. While the exact mechanism of action is still subject to some controversy, it is generally believed that the electrical energy blocks the signals in the afferent nerve fibers that transmit the pain signals to the brain.

[0013] A modification to this approach is to use percutaneous wires connected to electrodes placed nearer to the nerves (PENS or Percutaneous Electrical Nerve Stimulation). A wide variety of PENS or TENS stimulation parameters have been published, including high-frequency (HF; >10 Hz), low-frequency (LF; <10 Hz), variable-frequency (VF) and acupuncture-like (AL), which employs very low-frequency, high-amplitude stimulation. The intensity of the TENS or PENS stimulation (voltage or current) is generally adjusted to a level which achieves analgesia without causing irritation or pain from the stimulation itself. One such PENS device is described in U.S. Pat. No. 6,671,557.

[0014] Implantable devices for electrical stimulation of peripheral nerves for control of pain have been described. For example, U.S. Pat. No. 7,324,852 B2 describes an implantable electrical stimulation device with a plurality of electrodes that are implanted subcutaneously and are stimulated in a pre-determined pattern to provide pain relief.

[0015] A Spinal Cord Stimulator (SCS) is an implanted electrical stimulation device with one or more electrodes that are placed adjacent or near to the spinal cord, with the goal of blocking the pain signals from being transmitted via the spinal cord to the brain. Although SCS was originally designed and approved for radicular pain (sciatica), the technique is increasingly being used for lower back pain. Spinal cord stimulators may be self-powered (i.e., contain a primary battery or cell) or may include a rechargeable battery (i.e., a secondary battery or cell), as described for example, in U.S. Pat. No. 6,516,227.

[0016] The key drawback with all of the previously known electrical stimulation techniques that seek to block the pain signals (TENS, PENS, SCS and RF Ablation of the nerves) is that relief, if obtained, is usually only temporary, and repeated or continuous therapies are needed.

[0017] U.S. Patent Application Publication No. US2008/0228241 to Sachs, assigned to the assignee of the present invention, describes an implanted electrical stimulation device that is designed to restore neural drive and rehabilitate the multifidus muscle. Rather than masking pain signals while the patient's spinal stability potentially undergoes further deterioration, the stimulator system described in that application is designed to reduce the propensity for instability of the spinal column, which in turn is expected to reduce persistent or recurrent pain.

[0018] While the stimulator system described in the Sachs application seeks to rehabilitate the multifidus and restore neural drive, it does not provide relief of the pain during the application of the therapy. Thus, it is possible that for some patients the effectiveness of the therapy may be hindered by the continuation of pain, which may interfere with restoration of neural drive to the muscle or impede the patient's ability to tolerate the therapy. In addition, it is possible that as the tone of the multifidus muscle improves during use of the stimulator system described in the Sachs application, it may be desirable to reduce the stimulus amplitude, frequency or duration, or stimulation intervals.

[0019] In view of the foregoing, it would be desirable to augment the stimulator system described in the Sachs application with additional therapeutic modalities, such as the ability to alleviate pain during and between muscle stimulation. It therefore may be desirable to provide pain blocking stimulation to afferent nerve fibers simultaneously with muscle stimulation pulses, or at other times.

[0020] It further may be desirable, depending upon the severity of the pain experienced by a patient and the degree to which it interferes with rehabilitation of the multifidus muscle, to provide pain blocking by selectively ablating afferent nerve fibers in conjunction with the stimulation therapy described in the Sachs application.

[0021] It also would be desirable to combine the rehabilitative stimulation therapy described in Sachs with a capability to monitor muscle performance during the stimulation therapy, and to adjust the applied stimulation pulses to account for changes in the muscle tone and neural drive. In addition, it would be desirable to detect the duration, frequency and strength of muscle contractions to further reduce the patient's perception of pain resulting from the muscle stimulation therapy, for example, to avoid spasm.

SUMMARY OF THE INVENTION

[0022] In view of the drawbacks of previously-known methods and apparatus for treating back pain, the stimulator

system of the present invention provides a neuromuscular electrical stimulation system designed to rehabilitate spinal stability and restore neural drive, while providing additional therapeutic modalities, such as the ability to alleviate pain during and between muscle stimulation intervals. In accordance with the principles of the present invention, an implantable neuromuscular electrical stimulation system is provided that includes one or more of a number of additional therapeutic modalities: a module that provides analgesic stimulation; a module that monitors muscle performance and adjusts the muscle stimulation regime; and/or a module that provides longer term pain relief by selectively and if necessary repeatedly ablating afferent nerve fibers.

[0023] Accordingly, one embodiment of the stimulator system of the present invention combines circuitry to stimulate and rehabilitate the multifidus muscle with circuitry to stimulate afferent nerves to alleviate back pain during and between muscle stimulation intervals. The analgesic pulse regime may be applied to afferent nerve fibers simultaneously with muscle stimulation pulses, or at other times.

[0024] In an alternative embodiment, circuitry to stimulate and rehabilitate the multifidus muscle may be combined with circuitry that achieves pain blocking by selectively and repeatedly ablating afferent nerve fibers.

[0025] In still another embodiment, circuitry to stimulate and rehabilitate the multifidus muscle may be combined with circuitry to monitor muscle performance during the stimulation therapy, and to adjust the applied stimulation pulses to account for changes in the muscle tone and neural drive. For example, such performance feedback circuitry may detect the duration, frequency and strength of muscle contractions to further reduce the patient's perception of pain resulting from the muscle stimulation therapy, for example, to avoid spasm.

[0026] It should be appreciated that while the foregoing additional modalities are described in the context of a neuromuscular electrical stimulation system, such as described in the foregoing Sachs application, such modules may be packaged separately or in other combinations for applications other than treating back pain. For example, the RF ablation module may be implemented as a standalone implantable system for selectively ablating unresectable tumors located in the liver, brain, thyroid, pancreas, kidney, lung, breast, or other body structures, thereby avoiding the need for repeated reoperations. Alternatively, the RF ablation module may be combined with the analgesic stimulation module, such that the analgesic module provides continual pain relief while the RF ablation module provides intermittent ablation of selected afferent nerve fibers or tissue. As an additional example, the analgesic stimulator module may be combined with the performance feedback module, to provide an implantable stimulator that monitors muscle exertion and may adjust the stimulatory regime applied to the afferent nerves to maintain patient comfort.

[0027] The implantable electrical stimulation system of the present invention includes an implantable housing connected to at least one or more electrodes placed in appropriate anatomical locations and connected by leads to the housing. Feedthroughs (preferably hermetically sealed) connect the leads to the internal electronic circuitry. Stimulation electrodes may be logically connected in pairs to a stimulation channel designed to supply the stimulation regime needed for the therapeutic modality chosen for that electrode pair. The stimulator system may be arranged so that a different therapeutic modality may be applied to selected electrode pairs

simultaneously. For example, the stimulator may apply neuromuscular electrical stimulation to the medial branch of the dorsal ramus to effect contraction and rehabilitation of the multifidus muscle, while simultaneously applying electrical stimulation to a different arrangement of electrodes placed adjacent to the spinal cord to effect spinal cord stimulation to relieve pain.

[0028] In general, the stimulator system includes an implantable housing including a controller, a memory, a power source (e.g., battery or cell), a telemetry system (e.g., transceiver), one or more modules containing therapeutic circuitries (e.g., muscle stimulation, analgesic stimulation, performance feedback or RF ablation) coupled to the electrodes via an electrode switching circuit, and one or more sensors. The controller preferably comprises a processor, nonvolatile memory for storing firmware, implant identification information, and system and environmental data, and volatile memory that serves as a buffer for computations and instructions during execution and firmware updating. The controller preferably is coupled to battery, transceiver, electrode switching circuit, therapeutic module circuitries and sensors to monitor system status and to activate the various therapeutic module circuitries in accordance with the programming stored in the memory. The battery (or cell) can be a primary or secondary (rechargeable) configuration that preferably uses long-lasting lithium chemistry (e.g., lithium-ion or lithium polymer). If rechargeable, the battery is coupled to an inductive charging circuit, thereby enabling the battery to be periodically coupled to an external control system for charging. A radio frequency transceiver preferably is employed in the device for transmitting system information to, and receiving information from, the external control system, including system performance data, logged physiological data, commands, and firmware upgrades.

[0029] The stimulator system further comprises an external control system that may be coupled to the stimulator housing to supply power to the power source, to program/reprogram the controller, and to download system parameters and data stored within the memory. The external control system may be configured to transfer energy to the power source via inductive coupling. In a preferred embodiment, the external control system comprises a housing containing a controller, radio transceiver, inductive charging circuit and power source. The controller is coupled to the inductive charging circuit, power source, radio transceiver, and memory for storing information to be transmitted between the external control system and the implantable housing. The external control system may include a data port, such as a USB port or Bluetooth wireless connection, that permits the external control system to be coupled to a conventional computer, such as a personal computer or laptop computer, to configure the stimulation programs input to the stimulator and to review and analyze data received from the stimulator.

[0030] The stimulator system further may comprise monitoring and control software, configured to run on a conventional personal computer, laptop computer, "smart phone" or other computational device that enables the patient's physician to configure and monitor operation of the external control system and stimulator. The software may include routines for controlling any of a number of parameters associated with operation of the various therapeutic module circuitries incorporated in the stimulator. The software further may be configured, for example, to send immediate commands to the stimulator to start or stop muscle or analgesic stimulation, to

perform RF ablation, or to take a current reading of muscle activity and adjust the stimulation regime(s), or to change the electrodes used to apply stimulation. Finally, the software may be configured to download data collected from the stimulator and stored on the external control system, such as during a patient visit to the physician's office.

[0031] Methods of operating the stimulator system of the present invention also are provided. The implantable portion of the stimulator may be placed subcutaneously using interventional radiologic techniques including radiographic imaging or ultrasound, while the electrode leads may be placed using surgical, percutaneous, or minimally invasive techniques. The stimulator preferably is programmed using radio frequency coupling of the transceivers in the stimulator and the external control system, while power is supplied to the battery of the stimulator by coupling the inductive charging circuits of the stimulator and external control system. Additional details of methods of implanting and operating a stimulator system in accordance with the present invention are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] FIG. 1 is a schematic view of an exemplary embodiment of a stimulator system constructed in accordance with the principles of the present invention.

[0033] FIG. 2 is a side view of the implantable portion of the stimulator system of FIG. 1.

[0034] FIG. 3 is a generalized block diagram of the stimulator of FIG. 2.

[0035] FIG. 4 is a schematic diagram of a first embodiment of the stimulator of FIG. 3, wherein the stimulator is configured to deliver both neuromuscular stimulation and analgesic stimulation to afferent nerve fibers.

[0036] FIG. 5 is a schematic diagram of a second embodiment of the stimulator of FIG. 3 wherein the stimulator is configured to deliver neuromuscular stimulation, monitor the effects of the applied stimulation, and adapt the stimulation regime to improve muscle toning and reduce patient discomfort.

[0037] FIG. 6 is a schematic diagram of an alternative embodiment of the apparatus of the present invention that provides a selective ablation capability.

[0038] FIG. 7 is a schematic diagram of a further alternative embodiment of the stimulator of the present invention that includes neuromuscular stimulation, pain reduction, performance feedback and selective nerve ablation capabilities.

[0039] FIGS. 8A and 8B are, respectively, a plan view and detailed view of an exemplary electrode constructed in accordance with the principles of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0040] System Overview

[0041] Referring to FIG. 1, an overview of an exemplary stimulator system constructed in accordance with the principles of the present invention is provided. In FIG. 1, components of the system are not depicted to scale on either a relative or absolute basis. Stimulator system 10 comprises implantable stimulator 20 and external control system 30. In the illustrated embodiment, software may be installed and run on a conventional laptop computer, and used by the patient's physician to program external control system 30 and/or to provide programming that is communicated by external control system 30 to stimulator 20. During patient visits, external

system **30** may be coupled, either wirelessly or using a cable, to the physician's computer to download for review data stored on stimulator **20**, or to adjust the operational parameters of the stimulator.

[0042] In FIG. 1 implantable stimulator **20** is connected to a plurality of electrode leads. Illustratively, electrode lead **21** is connected to electrode pair **22**, which is situated close to or around a peripheral nerve N where the nerve enters skeletal muscle SM, which may be a multifidus muscle. Electrode pair **22** may deliver neuromuscular electrical stimulation ("NMES") pulses to nerve N that induce contraction of muscle SM to effect contraction of the muscle, and restoration of neural control and rehabilitation of the muscle, as described in the aforementioned U.S. Patent Application Publication No. US2008/0228241 to Sachs. Electrode lead **23** is illustratively disposed with electrode pair **24** adjacent or near to peripheral nerve P, such that electrical stimulation may be applied to achieve pain control in the region served by the peripheral nerves. Electrode lead **25** illustratively includes quadripolar electrode array **26**, which is placed near spinal cord S in a manner well known to one skilled in the art to deliver Spinal Cord Stimulation therapy that reduces or blocks the transmission of pain signals to the patient's brain B.

[0043] Implantable stimulator **20** is controlled by, and optionally powered by, external control system **30**, which communicates with stimulator **20** via antenna **31**, which may comprise an inductive coil configured to transmit power and communicate information in a bidirectional manner across skin SK. The technology for antenna **31** is well known to one skilled in the art and may include a magnet, a coil of wire, a longer range telemetry system (such as using MICS), or technology similar to a pacemaker programmer. Alternatively, coil **30** may be used to transmit power only, and separate radio frequency transmitters may be provided in external control system **30** and stimulator **20** for establishing directional data communication.

[0044] Referring now to FIG. 2, an exemplary embodiment of implantable stimulator **20** coupled to electrode lead **27** is described. As is common with other active implantable medical devices, the stimulator electronics are housed in a hermetically sealed metal housing **28**. Housing **28** may comprise titanium or other biocompatible material, and includes connector block **29** that permits allows electrode lead **27** to be electrically coupled to the electronics within housing **28**. While only one electrode lead **27** is shown coupled to connector block **29**, it should be understood that multiple leads may be connected to connector block **29**, as shown in FIG. 1. Electrode lead **27** contains a plurality of electrodes **27a-27d** that may be used for multiple purposes, as described in detail below. The construction of electrode lead, the electrode design and manufacture, and connector block **29** are all well known to those skilled in the art. As will also be understood by one of skill in the art, an electrode lead may contain more or fewer than four electrodes, as described in detail below with respect to FIGS. 8A and 8B.

[0045] With respect to FIG. 3, a generalized schematic diagram of the internal functional components of implantable stimulator **20** is now described. Stimulator **20** includes controller **40**, telemetry system **41** coupled to antenna **42** (which may be inside or external to the hermetic housing), power supply **43**, electrode switching array **44**, system sensors **45**, and therapeutic circuitry modules **46** and **47**. Electrode switching array **44** is selectively coupled to terminal array **48**,

which is housed in connector block **29** and enables stimulator **20** to be coupled to one or more electrode leads, as shown in FIG. 1.

[0046] Controller **40** may comprise a commercially available microcontroller unit including a programmable microprocessor, volatile memory, nonvolatile memory such as EEPROM for storing programming, and nonvolatile storage, e.g., Flash memory, for storing a log of system operational parameters and patient data. Controller **40** is coupled to telemetry system **41** that permits transmission of energy and data between implantable stimulator **20** and external control system **30**. Controller **40** also is coupled to therapeutic circuitry modules **46** and **47** that provide any of a number of complimentary therapeutic stimulation, analgesic, feedback or ablation treatment modalities as described in detail below. Controller **40** further may be coupled to electrode switching array **44** so that any set of electrodes of the electrode leads may be selectively coupled to therapeutic circuitry modules **46** and **47**. In this way, an appropriate electrode set may be chosen from the entire selection of electrodes implanted in the patient's body to achieve a desired therapeutic effect. Electrode switching array **44** preferably operates at high speed, thereby allowing successive stimulation pulses to be applied to different electrode combinations.

[0047] Power supply **43** powers the electrical components of implantable stimulator **20**, and may comprise a primary cell or battery, a secondary (rechargeable) cell or battery or a combination of both. Alternatively, power supply **43** may not include a cell or battery, but instead comprise a capacitor that stores energy transmitted through the skin via a Transcutaneous Energy Transmission System (TETs), e.g., by inductive coupling. Stimulator **20** may be programmed and/or controlled by, and may upload stored system and operational data to external control system **30** via telemetry system **41**. In a preferred embodiment, power supply **43** comprises a lithium ion battery.

[0048] System sensors **45** may comprise one or more sensors that monitor operation of the systems of implantable stimulator **20**, and log data relating to system operation as well as system faults, which may be stored in a log for later readout using the external control system. Sensors **45** may include, for example, a humidity sensor to measure moisture within housing **28**, which may provide information relating to the state of the electronic components, or a temperature sensor, e.g., for measuring battery temperature during charging to ensure safe operation of the battery. System sensors **45** also may include a 3-axis accelerometer for determining whether the patient is active or asleep and to sense overall activity of the patient, which may be a surrogate measure for clinical parameters (e.g., more activity implies less pain), and/or a heart rate or breathing rate (minute ventilation) monitor, e.g., which may be obtained using one or more of the electrodes disposed on the electrode leads. Data from the system sensors may be logged by controller **40** and stored in nonvolatile memory for later transmission to external controller **30** via telemetry system **41**.

[0049] If system sensor **45** includes an accelerometer, it may be used to determine the orientation of stimulator **20**, and by inference the orientation of the patient, at any time. For example, after implantation, external control system **30** may be used to take a reading from the implant, e.g., when the patient is lying prone, to calibrate the orientation of the accelerometer. If the patient is instructed to lie prone during therapy delivery, then the accelerometer may be programmed

to record the orientation of the patient during stimulation, thus providing information on patient compliance.

[0050] Implantable stimulator 20 illustratively includes two therapeutic circuitry modules 46 and 47, although more or fewer circuitry modules may be employed in a particular embodiment depending upon its intended application. As described in greater detail below with respect to further embodiments, therapeutic circuitry modules 46 and 47 may be configured to provide different types of stimulation, either to induce muscle contractions or to block pain signals in afferent nerve fibers, to monitor muscle contractions induced by stimulation and vary the applied stimulation regime as needed to obtain a desired result, or to selectively and intermittently ablate nerve fibers to control pain and thereby facilitate muscle rehabilitation. As shown in FIG. 3, the therapeutic circuitry modules are coupled to and controlled by controller 40.

[0051] Typical stimulation parameters provided for different requirements are summarized below, and will be well known to those skilled in the art:

[0052] For neuromuscular electrical stimulation (NMES):

- [0053] Bipolar electrode pairs
- [0054] Biphasic rectangular charge balanced
- [0055] 0.5-500 ms pulse width (adjustable to control intensity)
- [0056] 10-30 Hz (to achieve tetanic contraction)
- [0057] Constant current, <50 mA (<50V)

[0058] For PENS type stimulation:

- [0059] Multiple bipolar electrode system
- [0060] Biphasic pulses
- [0061] 20-40 Hz (including possibility of variable frequency over time of application of therapy)
- [0062] Constant current (typically 5-20 mA)

[0063] For Spinal Cord Stimulation:

- [0064] Multiple electrode configurations
- [0065] Biphasic rectangular charge balanced
- [0066] Typically 500 μ sec pulse width
- [0067] Current control (preferred) or voltage control, typically up to 10 mA into a 1K Ω load

[0068] For Radio Frequency Ablation:

- [0069] 450-500 KHz
- [0070] RF heating energy

[0071] Embodiments comprising specific combinations of therapeutic circuitry modules in accordance with the principles of the present invention are described below.

[0072] Combination Stimulator for Neuromuscular Electrical Stimulation and Pain Relief

[0073] Referring now to FIG. 4, a first embodiment of a neuromuscular electrical stimulation is described, which provides both stimulation to improve muscle tone and neural drive, while also providing stimulation to block or reduce transmission of pain along afferent nerve fibers. In the schematic of FIG. 4, implantable stimulator 50 includes controller 51, telemetry system 52 coupled to antenna 53, power supply 54, electrode switching array 55, system sensors 56, and NMES circuitry module 57 and analgesic stimulation circuitry module 58. Electrode switching array 55 is selectively coupled to terminal array 59, which is coupled to the connector block 29 (see FIG. 2) and enables stimulator 50 to be coupled to one or more electrode leads.

[0074] Each of components 51 to 59 operates in the manner described above for the embodiment of FIG. 3. More specifically, controller 51 preferably includes a programmable microprocessor, volatile memory, nonvolatile memory, and

nonvolatile storage, and is coupled to and controls operation of telemetry system 52, NMES circuitry module 57, analgesic stimulation circuitry module 58, and electrode switching array 55. Power supply 54 powers the electrical components of implantable stimulator 50, and may comprise a primary cell or battery, a secondary cell or battery, a combination of both or neither. In the latter case, power supply 54 may comprise a capacitor that stores energy transmitted through the skin via TETS. Stimulator 50 may be programmed and/or controlled by, and may upload stored system and operational data to external control system 30 via telemetry system 52. System sensors 56 may comprise one or more sensors that monitor operation of stimulator 50, as well as patient parameters, such as movement, heart rate, etc., and may log data relating to these parameters for later readout using the external control system.

[0075] In the embodiment of FIG. 4, NMES circuitry module is configured to provide stimulatory pulses to the nerves innervating, or directly to the muscle fiber of, the multifidus or other selected muscle group to cause a predetermined series of muscle contractions during a predetermined number of sessions to enhance muscle tone and improve neural drive in the muscle, as described in the above published application to Sachs, U.S. Patent Application Publication No. US 2008/0228241, the entirety of which is incorporated herein by reference.

[0076] Some patients receiving stimulator 50 may experience back pain due to previous injury and/or loss of muscle tone, while other patients may find the contractions induced by operation of the NMES circuitry to be unpleasant. Accordingly, stimulator 50 further includes analgesic stimulation circuitry module 58 to block or reduce pain associated with the previous injury or muscle contractions induced by the NMES therapy. As depicted in FIG. 1, in one preferred application of stimulator 50 (corresponding to stimulator 20 in FIG. 1), electrode pair 22 is situated on the medial branch of the dorsal ramus to deliver NMES pulses that cause muscle contraction to effect restoration of neural drive to and rehabilitation of the multifidus muscle. Analgesic stimulation circuitry module 58 may simultaneously be coupled to electrode pair 34, via electrode lead 23, and quad electrode 26, via electrode lead 25, to block or reduce pain signals generated in spinal cord S or peripheral nerve P. In addition, electrode pair 22 also may be used, e.g., by controller 51 switching electrode switching array 55 to couple electrode pair 22 to analgesic stimulation circuitry module 58, to deliver higher frequency stimulation to block afferent pain signals. In this manner, it is expected that NMES therapy may be provided while reducing patient discomfort and pain associated with any pre-existing injury.

[0077] Stimulator 50 and the electrodes also may be configured such that one set of electrodes is used to simulate the tissues on one side of the body, and another set of electrodes is used to simulate tissues on the other side of the body. In this manner, the stimulator and electrode system can be configured to deliver unilateral or bilateral stimulation, or a combination of electrodes stimulating tissues in no particular geometric arrangement.

[0078] Alternatively, a plurality of electrodes may be implanted on or adjacent to the medial branch of the dorsal ramus, such that one pair delivers NMES via circuitry module 57 to effect contraction of the multifidus muscle, and another pair simultaneously or successively delivers higher frequency stimulation via circuitry module 58 to block the pain signals

in the afferent fibers. The pairs of electrodes may include one or more common electrodes. The timing of the different electrical stimulation delivered offers several options. For example, the pain blocking stimulation may occur simultaneously with the NMES stimulation, may be multiplexed with the NMES stimulation (i.e., time wise interleaved so that stimulation pulses are not delivered simultaneously on both electrode pairs), in an alternating manner (i.e., NMES then pain blocking and so on), or episodically, such as NMES for a period without pain blocking stimulation, and then pain blocking stimulation when the NMES is not being delivered.

[0079] In a preferred embodiment intended for clinical applications, NMES stimulation is applied to the multifidus in sessions, typically one hour per day over a period of a few weeks. Such a regime is similar to conventional strength training by physical exercise which typically follows a similar time course. In preparation for the sessions of NMES strength training, stimulator 50 may be used to apply SCS therapy to block or dampen the pain signals which may arise from the NMES exercise regime. In this way, the desired therapeutic effect of restoration of neural drive and rehabilitation of the multifidus may occur without substantial pain or discomfort. For patients afflicted with severe back or radicular pain, stimulator 50 offers the capability to apply SCS therapy at the same time as NMES rehabilitation therapy for the multifidus.

[0080] In one embodiment, the patient may have access to external control system 30, and can thus activate implantable stimulator 50 in accordance with a rehabilitation plan developed jointly with his or her physician. In this case, controller 51 may be programmed to provide a delay of specified duration between activation of the stimulator and initiation of the stimulation pulses. This delay allows the patient to assume a comfortable position before the stimulation is applied, e.g., by lying prone. The external control system also may include a multi-functional user interface, including a range of patient operated inputs (e.g., buttons, knobs, touch screen, etc.) that allows activation or suspension of different types of stimulation.

[0081] In another embodiment, implantable stimulator 50 may be programmed to ramp up and ramp down the strength and duration of the stimulation pulses. This can be done in at least one of two manners. In the first manner, the stimulation pulse intensity is increased gradually (e.g., over 0.5 to 1 second) to a programmed maximum value to elicit the desired muscle contraction and then ramped down slowly. In this way, the muscle contraction has a smooth on and off sensation for the patient. In the second manner, the therapeutic dose (i.e., the number of contractions of a therapy period) are programmed to increase gradually until the desired level is achieved and then decrease gradually to zero, in much the same way that a good muscle strength training regime provides a stretching or warm-up phase and cool-down phase. In this mode of operation, stimulator 50, via either input to the external control system or at a pre-determined time, and following the stimulation delay (if any), ramps up the stimulation amplitude from a low level (e.g., beginning at zero) to a pre-determined maximum level over a pre-determined period of time. Likewise, upon conclusion of the stimulation therapy period, stimulator 50 ramps the amplitude down from the pre-determined maximum level to a low level. It is expected that this embodiment, which provides a gradual increase and decrease of stimulation intensity, will provide a more comfortable experience for some patients.

[0082] As discussed above, implantable stimulator 50 preferably contains nonvolatile memory for storage, and is programmed to log data during the therapy session, along with internal parameters of the device. Such data logging may also record data from system sensors 56, which may be downloaded from stimulator 50 using the external control system, to provide an indication of the effectiveness of the therapy. For example, if the sensors include a three axis accelerometer, then a patient's overall activity level on an hourly, daily, or weekly basis may be logged, for example, by recording an integral of all accelerometer measurements. The sensors also may include circuitry for determining heart rate, and such circuitry may be used to record the patient's maximum heart rate as a measure of overall activity.

[0083] In clinical use, the stimulator 50 is implanted subcutaneously, and system sensors 55 may be used to record and log baseline (i.e., pre-therapy) patient parameters such as total activity and maximum heart rate. The therapy then is enabled, and the data logging may be used to assess progress of the therapy and the patient's change in status. For example, if the accelerometer shows increased overall activity, this would indicate that the pain, which was previously inhibiting activity, had been ameliorated. Such data may be used by the physician to adjust the therapy by adjusting the programming of stimulator 50 using external control system 30, and/or such information may be provided to the patient as encouraging feedback.

[0084] Stimulator for Neuromuscular Stimulation with Performance Feedback

[0085] Referring now to FIG. 5, another embodiment of a stimulation system constructed in accordance with the principles of the present invention is described, in which the implantable stimulator provides a NMES stimulator therapy and further has the capability to monitor the progress of the therapy and to revise the therapy regime to reflect changes in the muscle characteristics resulting from the therapy. Such revision may be made by way of a physician periodically reprogramming the NMES parameters using external control system 30, or alternatively the NMES stimulation parameters may be adjusted dynamically and automatically modified to keep the muscle contraction at a certain predetermined efficacious and tolerable level. In some embodiments, stimulator 60 may provide a closed loop feedback system, in which the system instantaneously responds to physiological changes affecting the stimulation characteristics of the muscle.

[0086] Although a primary application of the inventive technology is to improve stability of the spine, it also may be advantageously applied in other areas of muscle rehabilitation, e.g.:

[0087] Restoration of function of leg muscles to allow standing and walking in paraplegic patients (referred to as Functional Electrical Stimulation (FES));

[0088] Rehabilitation of injured or weakened muscles following surgery or correction of osteoarthritis, such as rehabilitation of the quadriceps after knee surgery;

[0089] Restoration of neural drive and rehabilitation of muscles that are part of the stabilizing system in the back, including the lumbar multifidus;

[0090] Providing stimulation to effect breathing (diaphragm and/or intercostal muscles); and

[0091] Providing mechanical muscle power to perform a bodily function, for example, as in cardiomyoplasty.

[0092] The implantable NMES stimulator described in the above-incorporated Sachs application discusses that the

parameters for electrical stimulation may be programmed into the stimulator following testing by the physician of stimulation thresholds. Therapy parameters such as duration, frequency and strength of contraction also may be programmed into the stimulator according to the patient's needs, and the stage of therapy delivery. In some cases it is expected that the programmed parameters may need to be changed, for example during the course of the therapy program as the muscle becomes rehabilitated.

[0093] Stimulator 60 of FIG. 5 is designed to improve the NMES performance and reduce the need for frequent reprogramming by monitoring muscle performance during therapy, and adjusting the stimulation parameters accordingly. More specifically, implantable stimulator 60 includes controller 61, telemetry system 62 coupled to antenna 63, power supply 64, electrode switching array 65, system sensors 66, and NMES circuitry module 67 and muscle performance monitoring circuitry module 68. Electrode switching array 65 is selectively coupled to terminal array 69, which is coupled to the connector block 29 (see FIG. 2) and enables stimulator 60 to be coupled to one or more electrode leads. Electrode switching array 65 also may include connection 69a to the housing of stimulator 60, so that the housing functions as an electrode.

[0094] Each of components 61 to 67 and 69 operates in the manner described above for the embodiment of FIG. 3. Controller 61 preferably includes a programmable microprocessor, volatile memory, nonvolatile memory, and nonvolatile storage, and is coupled to and controls operation of telemetry system 62, NMES circuitry module 67, muscle performance monitoring circuitry module 68, and electrode switching array 65. Power supply 64 powers the electrical components of implantable stimulator 60, and may comprise a primary cell or battery, a secondary cell or battery, a combination of both or neither. In the latter case, power supply 64 may comprise or include a capacitor that stores energy transmitted through the skin via a Transcutaneous Energy Transmission System ("TETS"). Stimulator 60 may be programmed and/or controlled by, and may upload stored system and operational data to external control system 30 via telemetry system 62. System sensors 66 may comprise one or more sensors that monitor operation of stimulator 60, as well as patient parameters, such as movement, heart rate, etc., and may log data relating to these parameters for later readout using the external control system.

[0095] In accordance with one aspect of the present invention, stimulator 60 further comprises muscle performance monitoring circuitry module 68 coupled to controller, and designed to monitor one or more parameters of muscle performance. The measured parameters may be used to automatically modify the therapy delivered by NMES circuitry module 67, and/or to provide stored and telemetered information via telemetry system 62 and external control system 30 that enable the physician to modify the parameters. In one preferred embodiment, muscle performance monitoring circuitry module 68 may be coupled through electrode switching array 65 to selected electrodes coupled to terminal array 69 to measure electrical parameters of the tissue, such as impedance, or evoked potential from the stimulation. Circuitry module 68 may in addition be coupled to system sensor 66, for example, to obtain data from an accelerometer or other movement transducer, and/or temperature or pressure. Circuitry module 68 also may be configured to receive inputs

from other types of body sensors such as are known in the art, including those monitoring chemical properties (e.g., pH sensor, etc.).

[0096] Circuitry module 68 preferably includes at least one listening amplifier configured for electromyography (EMG). EMG is an electrical signal produced by muscle when it contracts, and the strength (power) of the EMG is an indicator of strength of muscle contraction. Configuration of an amplifier for measurement of EMG, e.g., gain, frequency response, impedance, etc., is well known to those skilled in the art. As described in Stokes, Ian A F, Sharon M Henry, and Richard M Single, "Surface EMG electrodes do not accurately record from lumbar multifidus muscles," Clinical Biomechanics (Bristol, Avon) 18, no. 1 (January 2003): 9-13, it is known that certain muscles, such as the deep fibers of the lumbar multifidus, surface EMG provides an unreliable signal. Accordingly, the implantable electrode leads used with stimulator 60 advantageously are expected to provide a useful EMG signal.

[0097] In another embodiment, circuitry modules 67 and 68 may be configured to perform impedance measurements, in a manner similar to that described in U.S. Pat. No. 6,406,421 B1 to Grandjean et al. As is well known, an electrical impedance measurement may be performed by injecting a current through one pair of electrodes, and measuring voltage through a different pair of electrodes disposed approximately along the same geometric path. See, e.g., Rutkove, S. B., "Electrical impedance myography: Background, current state, and future directions", Muscle & Nerve 40, No. 6 (December 2009): 936-46. In one implementation, a first pair of electrodes consisting of the stimulator housing (via connection 69a) and one or more of electrodes disposed on an electrode lead may be used to inject current into the tissue (e.g., from NMES circuitry module 67), while voltage is measured by circuitry module between the stimulator housing and a different set of one or more of electrodes on the electrode leads. Alternatively, the same set of electrodes (including the stimulator housing) may be used for both injecting current and measuring the resulting voltage.

[0098] The foregoing impedance measurements may be of direct current (DC) or alternating current (AC). With AC impedance measurement, additional useful information may be obtained such as phase, frequency spectrum, and changes in parameters. The electrical impedance so measured is an indication of the tissue volume and tissue organization (anisotropy) between the measurement electrodes, as reported in Garmirian et al., "Discriminating neurogenic from myopathic disease via measurement of muscle anisotropy", Muscle Nerve, 2009 January; 39 (1): 16-24. See also, Miyatani, M., et al., "Validity of estimating limb muscle volume by bioelectrical impedance", J. Applied Physio. (Bethesda, Md. 1985) 91, no. 1 (July 2001): 386-94. Accordingly, judicious placement of the electrodes and the stimulator housing will ensure that only the tissue of interest (e.g., the target muscle) is in the path of the injected and measured voltage. As a muscle contracts, its dimensions change, and this will generate a change in electrical impedance. Thus, measurement of electrical impedance may be used as a surrogate measure of muscle contraction.

[0099] In another embodiment, circuitry module 68 may include or be coupled to a transducer that senses mechanical motion, such as vibration, acceleration or deflection, and may include piezoelectric polymers (e.g., PVDF) placed on a lead. The signal from such a transducer provides a surrogate measure of muscle contraction. In a further alternative embodi-

ment, circuitry module **68** may include or be coupled to a transducer that senses pressure, such as a MEMS pressure sensors disposed on a lead, and which thus provides a surrogate measure of muscle contraction.

[**0100**] In yet another embodiment, stimulator **60** is configured to sense EMG from more than one muscle, using multiple electrode leads or multiple electrodes on a single lead that passes through more than one muscle. In this case, the listening amplifier of circuitry module **68** is multiplexed to listen for EMGs from more than one muscle. Alternatively, circuitry module **68** may include multiple listening amplifiers that are arranged to simultaneously listen to EMGs from more than one muscle. It is well-known, for example from Jaap van Dieen et al., "Trunk Muscle Recruitment Patterns," Spine Vol. 28, Number 8 pg 834-841, that the relative timing and amplitude of EMGs in trunk muscles during the performance of specific tasks is different between healthy individuals and patients experiencing low back pain due to spinal instability. In patients with spinal instability, recruitment patterns of the trunk muscles may be altered to compensate for the lack of spinal stability. The amplitude and timing of EMGs measured from multiple trunk muscles therefore may be used to diagnose the presence and degree of spinal instability, as well as the change of spinal instability during a course of therapy. The EMG data may be used to automatically modify treatment parameters, or such data may be stored for later review by the physician to assist in diagnosis and revision of the therapy parameters.

[**0101**] In the embodiment of FIG. 5, muscle performance monitoring circuitry module **68** is configured to measure muscle contraction induced by NMES circuitry module **67**, and to modify the therapeutic parameters as muscle performance changes. In particular, the initial therapeutic parameters, such as dose and duration of therapy session, are established and programmed into stimulator **60** using external control system **30**. Between therapy sessions, muscle performance may be monitored continuously or periodically using circuitry module **68**. When the change in measured muscle performance exceeds a predetermined physician selected threshold, circuitry module **68** may instruct controller **61** to modify the parameters for subsequent NMES therapy sessions. For example, if the monitoring parameters reveal that the muscle mass has increased, indicative of muscle rehabilitation, or contractility has decreased, then the therapy dose may be automatically reduced some pre-determined amount as previously programmed by the physician.

[**0102**] In an alternative embodiment, muscle performance may be used to inhibit muscle contraction. For example, in certain types of low back pain, pain is caused by spasm of certain muscles in the back. Such spasm is accompanied by continuous increase in EMG activity. In accordance with one aspect of the present invention, NMES stimulation may be used to inhibit muscle contraction by configuring the listening amplifier of circuitry module **68** to continuously or periodically measure EMG. If the EMG satisfies conditions indicating that muscle spasm has occurred, then NMES circuitry module is directed by controller **61** to apply stimulation to the nerve innervating the muscle in spasm to block conduction of signals from the nervous system which cause the muscle spasm, thereby preventing spasm. The stimulation provided by NMES circuitry module may be inhibited from time to time to allow circuitry module **68** to assess from the EMG

signal if the muscle is still in spasm; if spasm has ceased, then application stimulation by NMES circuitry module **67** is terminated.

[**0103**] In an alternative embodiment, muscle performance monitoring circuitry module **68** may be configured to measure a combination of EMG and tissue impedance to confirm that a muscle is in spasm, thereby improving the safety and reliability of the measurement. Muscle performance monitoring circuitry module **68** also may be used to track changes in activity and health of the muscle in response to neural activity. In other words, the amount of muscle contraction as determined by impedance measurement of tissue volume may be correlated to the amount of electrical activity in the muscle as determined by EMG. Further still, the electrodes and muscle performance monitoring circuitry module **68** may be configured to record electrical signals from the nerves as well as the muscle, such that a measurement of the EMG (and/or tissue volume) in response to neural activity may be used as an indication of the health of the muscle.

[**0104**] Muscle performance monitoring circuitry module **68** also may employ measurement of the change in muscle mass in response to NMES of the nerve to adjust the electrical stimulation parameters. In this case, an empirically derived transfer function may be determined that relates electrical stimulation parameters, such as current, pulse width, frequency and duration, to the strength of contraction of the muscle. Over time, this transfer function may change, for example, as a result of electrode changes from movement or tissue ingrowth. Thus, the strength of muscle contraction may be used to automatically adjust the electrical parameters of the NMES stimulation provided by circuitry module **67** to achieve a desired muscle contraction.

[**0105**] Stimulator with RF Ablation Capability

[**0106**] Referring to FIG. 6, in accordance with another aspect of the present invention, an implantable RF ablation device is described. Although a primary application of the inventive technology is pain reduction in connection with improving stability of the spine, the inventive technology may be advantageously applied in other areas, for example:

[**0107**] RF rhizotomy, in which a sensory nerve is ablated to prevent sensory signals (e.g., pain) from reaching the brain, such as rhizotomy of the medial branch of the dorsal ramus in patients with facet joint pain;

[**0108**] RF ablation of unresectable tumors located in the liver, brain, musculoskeletal system, thyroid and parathyroid glands, pancreas, kidney, lung, and breast, in which it is difficult to achieve complete tumor necrosis, leading to recurrence of the tumors and necessitating repeated RF ablation; and

[**0109**] Treatment of tumors in which the root of the tumor is located in tissue that is considered too risky for surgical intervention, such as tumors with roots in the digestive tract, uterine wall or certain oesophageal tumors, and for which regular repeat surgery is required to remove new growths.

[**0110**] The field of RF ablation is well developed, and parameters suitable for ablating nerve fibers and other tissues, such as RF energy, and attendant issues is well known to those of ordinary skill in the art. See, e.g., Gazelle et al., "Tumor ablation with radio-frequency energy", Radiology, December 2000; 217(3): 633-46 and Haemerrich et al, "Thermal tumour ablation: devices, clinical applications and future directions", Int. J. Hyperthermia, 2005 December; 21(8):755-60. To the inventors' knowledge, however, no one has suggested an RF

ablation device that is configured to be chronically implanted and capable of performing repeated RF ablation.

[0111] Referring now to FIG. 6, implantable device 70 is described, which is intended for chronic implantation to perform serial RF ablations in scenarios where it is necessary to repeat RF ablation of tissue in a particular region of the body after certain periods of time. The components of device 70 correspond closely to those described above with respect to the embodiment of FIG. 3, and includes controller 71, telemetry system 72 coupled to antenna 73, power supply 74, electrode switching array 75, system sensors 76, and terminal array 77. As in the preceding embodiments, electrode switching array 75 is selectively coupled to terminal array 77, which is coupled to the connector block 29 (see FIG. 2) that accepts one or more implantable electrode leads. Electrode switching array 75 also may include connection 77a to the housing of device 70, so that the housing functions as an electrode. In accordance with this aspect of the present invention, device 70 further comprises RF ablation circuitry module 78, as further described below.

[0112] Each of components 71 to 77 operates in the manner described above for the embodiment of FIG. 3. Controller 71 preferably includes a programmable microprocessor, volatile memory, nonvolatile memory, and nonvolatile storage, and is coupled to and controls operation of telemetry system 72, electrode switching array 75 and RF ablation circuitry module 78. Power supply 74 powers the electrical components of device 70, and may comprise a primary cell or battery, a secondary cell or battery, a combination of both, or neither. In the latter case, power supply 74 may comprise or include a capacitor (such as a super capacitor of technology known to those skilled in the art) that stores energy transmitted through the skin via TETS. Device 70 may be programmed and/or controlled by, and may upload stored system and operational data to external control system 30 via telemetry system 72. System sensors 76 may comprise one or more sensors that monitor operation of device 70, as well as patient parameters, such as tissue impedance, and may log data relating to these parameters for later readout using the external control system.

[0113] In accordance with this aspect of the present invention, device 70 further comprises RF ablation circuitry module 78 coupled to controller, and designed to periodically ablate tissue or nerve fibers using RF energy. Accordingly, controller 71 may be configured to control operation of the telemetry system 72 to receive energy wirelessly from external control system 30 and store that energy in power supply 74, and may be configured to communicate the amplitude of received power back to the external control system via telemetry system 72 or via modulation of the impedance of the antenna 73. To ensure that RF ablation is only carried out at the direction of the external control system, device 70 may not include battery or capacitor, but instead may be arranged so that it is energized only when in communication with the external control system.

[0114] Expected energy requirements for the RF ablation circuitry module are in a range of about 1-40 watts, depending upon the intended application. TETS systems with this power capacity are well known to those skilled in the art and have been used, for example, with artificial hearts or Left Ventricular Assist Devices (LVADs). However, the physical volume and other requirements of a high power TETS system may preclude its use in applications where the available surgical locations are limited. Thus, in an alternative embodiment, the TETS system may be of lower power capacity than the

requirements of the RF generator, and device 70 may include an energy storage element, such as a super capacitor or low impedance secondary (rechargeable) cell, for powering RF ablation circuitry module 78. In use, the TETS may operate continuously, such that a signal is generated when there is adequate energy stored in the implantable device to deliver the RF ablation energy at the desired power and for the desired time. As an example, a TETS system capable of transferring 1W may be used to supply RF energy delivery of 5W with 20% duty cycle.

[0115] In this embodiment, telemetry system 72 enables communications between the external control system and device 70, allowing the implantable device to receive device and RF ablation operating parameters, as well as communicate logged information such as impedance between electrodes, temperature data and battery status to the external control system. Telemetry system 71 also may provide programming to controller 71 to reconfigure the operative electrodes through which ablation energy is supplied using electrode switching array 75, thereby allowing any electrode of a plurality of electrodes to be configured as a cathode, an anode or unconnected. The housing of device 70 also may be configured as an electrode via connection 77a of terminal array 77. The foregoing capabilities provide flexibility in the location of ablation lesions and allow the physician to compensate for electrode movement after implantation.

[0116] System sensors 76 advantageously may be used to monitor the temperature of the tissue near the electrodes thru which energy for ablation is delivered. Typical tissue temperatures for RF ablation range from 50C to 130C, depending on the type of tissue being ablated and the time allocated to the ablation. System sensors 76 may comprise, e.g., temperature sensors disposed within the device housing, or alternatively may measure the temperature of the connection to the electrode leads, and use that data to infer or predict the tissue temperature. Temperature sensors may also be incorporated into the leads and placed closer to the tissue targeted for ablation. System sensors 76 may be used in a passive (measuring) mode, or alternatively may comprise part of a feedback control system that continually or intermittently adjusts power delivered by the RF ablation circuitry module so that the temperature of the ablated tissue is maintained between desired limits for safety and efficacy.

[0117] Referring now to FIG. 7, an implantable stimulator illustratively incorporating all of the therapeutic circuitry modules described for the preceding embodiments is described. Implantable stimulator 80 corresponds to stimulator 20 of FIG. 1, and is programmed and controlled and/or powered by external control system 30. Stimulator 80 is intended for use, for example, in a stimulator that provides NMES stimulation, analgesic stimulation to block or reduce afferent pain signals in a nerve, and permits periodic nerve ablation (such as rhizotomy). Further in accordance with this aspect of the present invention, stimulator 80 includes muscle performance monitoring circuitry that supports testing of nerve fibers prior to rhizotomy, which to guide proper selection of the ablation electrodes.

[0118] Stimulator 80 of FIG. 7 includes controller 81, telemetry system 82 coupled to antenna 83, power supply 84, electrode switching array 85, system sensors 86, terminal array 87, NMES circuitry module 88, analgesic stimulation circuitry module 89, muscle performance monitoring circuitry module 90, and RF ablation circuitry module 91. As in the preceding embodiments, electrode switching array 85 is

selectably coupled to terminal array **87** under the control of controller **81**, and enables any one or more of the therapeutic circuitry modules of stimulator **80** to be selectively coupled to selected electrodes of one or more electrode leads. Electrode switching array **85** also may include connection **87a** to the housing of stimulator **80**, so that the housing also may serve as an electrode.

[0119] Each of components **81** to **87** operates in the manner described above for the embodiment of FIG. 3. Controller **81** preferably includes a programmable microprocessor, volatile memory, nonvolatile memory, and nonvolatile storage, and is coupled to and controls operation of telemetry system **82**, electrode switching array **85**, NMES circuitry module **88**, analgesic stimulation circuitry module **89**, muscle performance monitoring circuitry module **90**, and RF ablation circuitry module **91**. Power supply **84** powers the electrical components of implantable stimulator **80**, and may comprise a primary cell or battery, a secondary cell or battery, a combination of both, or neither, as discussed above. Stimulator **80** may be programmed and/or controlled by, and may upload stored system and operational data to external control system **30** via telemetry system **82**. System sensors **86** may comprise one or more sensors that monitor operation of stimulator **80**, as well as various patient parameters as discussed above.

[0120] In accordance with this aspect of the present invention, stimulator **80** further comprises NMES circuitry module **88** and analgesic stimulation circuitry module **89**, as described above with respect to the embodiment of FIG. 4, muscle performance monitoring circuitry module **90** as described above with respect to the embodiment of FIG. 5, and RF ablation circuitry module **91** as described above with respect to the embodiment of FIG. 6. In this manner, a patient in need of spinal muscle rehabilitation and restoration of neural drive may have the full range of therapeutic modalities available. In particular, stimulator **80** as initially implanted by the physician, may be programmed to provide NMES stimulation and stimulation to block pain signals in afferent nerves. As muscle strength and contractility improve over the course of the therapy, the muscle performance monitoring circuitry module **90** may measure the progress of the therapy and adjust the NMES stimulation parameters or circumvent spasm. In addition, depending upon the patient's reported condition and measurement data provided by the muscle performance monitoring circuitry module **90**, the physician may periodically activate RF ablation circuitry module **91** to denervate selected nerve fibers.

[0121] Electrode Lead Systems

[0122] In view of the capabilities of the various implantable stimulators described herein, it may be advantageous to provide an electrode lead specially configured for use with such stimulators. Referring to FIGS. **8A** and **8B**, electrode leads configured to provide NMES stimulation to a nerve to cause muscle contraction; to stimulate a nerve to inhibit pain signals from propagating to the brain; to stimulate a nerve to inhibit motor nerve signals thereby reducing or stopping contraction of a muscle (e.g., in spasm); to record electrical signals such as electromyography or tissue impedance; or for performing in situ RF ablation are now described.

[0123] With respect to FIG. **8A**, electrode lead **100** carrying electrodes **101a** to **101f** is described. The number of electrodes may be as few as 1 and as many as may be realistically placed within the target anatomical space. Electrode configurations commonly used in the art include **1** (for unipolar stimulation), **2**, **4** (peripheral nerve stimulation), **8**, **16** (spinal

cord stimulators) or up to 22 electrodes (cochlear implants). For the purpose of this disclosure, distal-most electrode **101a** will be referred to as electrode #1, electrode **101b** will be electrode #2 and so on moving proximally along lead **100** up to the total number of electrodes.

[0124] When employed with an implantable stimulator as described herein that provides multiple independent current outputs, electrode lead **100** is capable of delivering multiple therapies simultaneously, in an overlaid fashion or staggered. Electrodes **101a** to **101f** may be sized and positioned relative to each other to allow for generation of a voltage field tailored to the specific type of stimulation, sensing or ablation desired for the given therapies.

[0125] In one embodiment, electrode lead **100** is placed parallel to a target nerve in a caudal to cranial orientation (with the cranial direction being the direction tending towards afferent neural activity). Then so positioned, electrodes **1** and **2**, which are most cranial, may be sized and spaced to allow for optimal blocking of afferent pain signals being transmitted along the nerve (for example the pain signals being carried from the facet joint along the medial branch). More caudally, electrodes **3** and **4** may be sized and spaced to allow for optimal recruitment of large fiber motor neurons. Because the action potentials required for activation of a muscle travel efferently, these potentials are not blocked by the more cranial blocking action of electrodes **1** and **2**. Finally, electrodes **5** and **6**, placed most caudally, may be sized and positioned for sensing and recording of muscle recruitment through capturing the EMG signal of the muscle, which may be processed, for example, by the muscle performance monitoring circuitry module as described above with respect to the embodiment of FIG. 4. Such an arrangement therefore allows for simultaneous blocking of pain arising from the facet joint, stimulation of the motor fibers of the nerve eliciting muscle contraction, and sensing of the elicited response (which would enable a closed loop system, improving device longevity and recruitment efficiency) without any of the stimulation pulses negatively impacting the performance of the others.

[0126] With respect to FIG. **8B**, alternative electrode lead **110** carrying electrodes **111a** to **111g** is described. Distal-most electrode **111a** again will be referred to as electrode #1, electrode **111b** will be electrode #2 and so on moving proximally along lead **111**. In the embodiment of FIG. **8B**, a blocking action of electrodes **1** and **2** may be used to mute the sensory perception of stimulation. In this manner, NMES stimulation therapy of the motor fibers in patients may be achieved where the patients would otherwise not tolerate the stimulation because of the resulting bi-directional action potential generated by neural stimulation. It also may be possible to use electrodes **5** and **6**, which will likely be placed intramuscularly, to record the volume EMG signal in the muscle. Changes in this signal over time may provide an indication of the degree to which motor control has been compromised due to injury. When such data are compared over time during the period after a therapy regime has been completed, the data may be used as a positive indicator that additional therapy may be required to maintain spinal stability.

[0127] While various illustrative embodiments of the invention are described above, it will be apparent to one skilled in the art that various changes and modifications may be made therein without departing from the invention. The

appended claims are intended to cover all such changes and modifications that fall within the true spirit and scope of the invention.

What is claimed:

1. A therapeutic electrical stimulation system comprising:
an implantable housing;

at least one electrode lead coupled to the housing and having a plurality of electrodes, the electrode lead configured to be implanted adjacent to a spinal tissue;
a first circuitry module disposed within the implantable housing and operatively coupled to the electrode lead, the first circuitry module configured to deliver electrical stimulation to a selected first subset of the plurality of electrodes to cause contraction of a spinal muscle associated with the spinal tissue; and

a second circuitry module disposed within the implantable housing and operatively coupled to the electrode lead, the second circuitry module configured to perform a function selected from the group consisting of: analgesic stimulation of afferent nerve fibers associated with the spinal tissue; muscle performance monitoring; stimulation of efferent nerve fibers associated with the spinal tissue to reduce spasm, and RF ablation.

2. The therapeutic electrical stimulation system of claim **1**, further comprising a controller disposed within the implantable housing and operatively coupled to the first and second circuitry modules.

3. The therapeutic electrical stimulation system of claim **2**, further comprising a telemetry system disposed within the implantable housing and operatively coupled to the controller.

4. The therapeutic electrical stimulation system of claim **3**, further comprising an external control system configured to wirelessly communicate with the telemetry system.

5. The therapeutic electrical stimulation system of claim **2**, further comprising a power source disposed within the implantable housing.

6. The therapeutic electrical stimulation system of claim **5**, further comprising an external control system configured to wirelessly transmit energy to the power source.

7. The therapeutic electrical stimulation system of claim **2**, further comprising an electrode switching array disposed with the implantable housing, the controller operatively coupled to the electrode switching array to select the first subset of the plurality of electrodes coupled to the first circuitry module.

8. The therapeutic electrical stimulation system of claim **7**, wherein the second circuitry is operatively coupled to a second subset of the plurality of electrodes, the controller selecting the second subset of the plurality of electrodes coupled to the second circuitry module.

9. The therapeutic electrical stimulation system of claim **8**, wherein the second subset of the plurality of electrodes is the same as the first subset of the plurality of electrodes.

10. The therapeutic electrical stimulation system of claim **1**, wherein the second circuitry module is configured to perform analgesic stimulation of afferent nerve fibers associated with the spinal tissue, further comprising a third circuitry module configured to perform a function selected from the group consisting of: muscle performance monitoring; stimulation of efferent nerve fibers associated with the spinal tissue to reduce spasm, and RF ablation.

11. The therapeutic electrical stimulation system of claim **1**, wherein the second circuitry module is configured to perform muscle performance monitoring, the second circuitry configured to measure muscle performance and to adjust the delivery of electrical stimulation by the first circuitry responsive to measured muscle performance.

12. The therapeutic electrical stimulation system of claim **1**, wherein the second circuitry module is configured to perform muscle performance monitoring using bioimpedance.

13. The therapeutic electrical stimulation system of claim **1**, wherein the second circuitry module is configured to perform muscle performance monitoring using electromyography.

14. The therapeutic electrical stimulation system of claim **1**, wherein the second circuitry module is configured to perform muscle performance monitoring using data indicative of mechanical motion.

15. The therapeutic electrical stimulation system of claim **2**, further comprising an accelerometer disposed within the implantable housing, the accelerometer configured to provide orientation data to the controller.

16. An implantable RF ablation system comprising:
an implantable housing;

at least one electrode lead coupled to the housing and having a plurality of electrodes, the electrode lead configured to be implanted adjacent to a target tissue;
an RF ablation circuitry module disposed within the implantable housing and operatively coupled to the electrode lead, the RF ablation circuitry module configured to deliver radio frequency energy to a selected subset of the plurality of electrodes to ablation of the target tissue.

17. The implantable RF ablation system of claim **16**, further comprising a controller disposed within the implantable housing and operatively coupled to the RF ablation circuitry module.

18. The implantable RF ablation system of claim **17**, further comprising a telemetry system disposed within the implantable housing and operatively coupled to the controller.

19. The implantable RF ablation system of claim **18**, further comprising an external control system configured to wirelessly communicate with the telemetry system.

20. The implantable RF ablation system of claim **16**, further comprising a power source disposed within the implantable housing.

21. The implantable RF ablation system of claim **20**, further comprising an external control system configured to wirelessly transmit energy to the power source.

22. The implantable RF ablation system of claim **16**, further comprising an electrode switching array disposed with the implantable housing, the controller operatively coupled to the electrode switching array to select the subset of the plurality of electrodes coupled to the RF ablation circuitry module.

23. The implantable RF ablation system of claim **16**, wherein the RF ablation circuitry module is configured to perform ablation of afferent nerve fibers associated with spinal tissue.

24. The implantable RF ablation system of claim **16**, further comprising an accelerometer disposed within the implantable housing, the accelerometer configured to provide orientation data to the controller.



US 20120277076A1

(19) **United States**

(12) **Patent Application Publication**

HUANG

(10) **Pub. No.: US 2012/0277076 A1**

(43) **Pub. Date: Nov. 1, 2012**

(54) **CORE MUSCLE GROUP TRAINING EQUIPMENT AND ITS METHOD OF USE**

(75) Inventor: **Mao Ying HUANG**, Changhua County (TW)

(73) Assignee: **DYACO INTERNATIONAL INC.**, Taipei City (TW)

(21) Appl. No.: **13/207,737**

(22) Filed: **Aug. 11, 2011**

(30) **Foreign Application Priority Data**

Apr. 27, 2011 (TW) 100114723

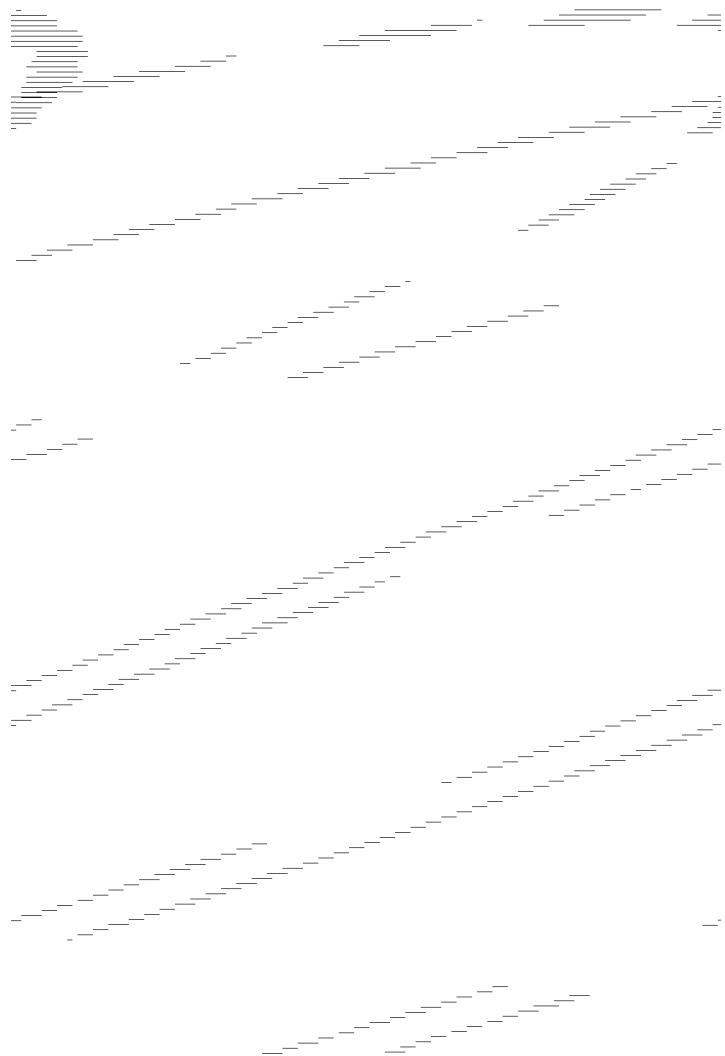
Publication Classification

(51) **Int. Cl.**
A63B 26/00 (2006.01)

(52) **U.S. Cl.** **482/142**

(57) **ABSTRACT**

A core muscle group training equipment includes a seat, a backrest located on the back side of the seat and a damping mechanism provided at the bottom side of the seat. When sitting on the seat and resting the back on the backrest, the user can selectively bend the upper body forwards and backwards to contract the proximal muscles, or keep the upper body immovable and move the lower body up and down to contract distal muscles. By means of biasing of the seat and the damping effect provided by the damping mechanism during operation, the muscle strength of the abdominal muscles is trained. When releasing the pressure, the damping mechanism returns the machine parts smoothly, preventing accidental injury.



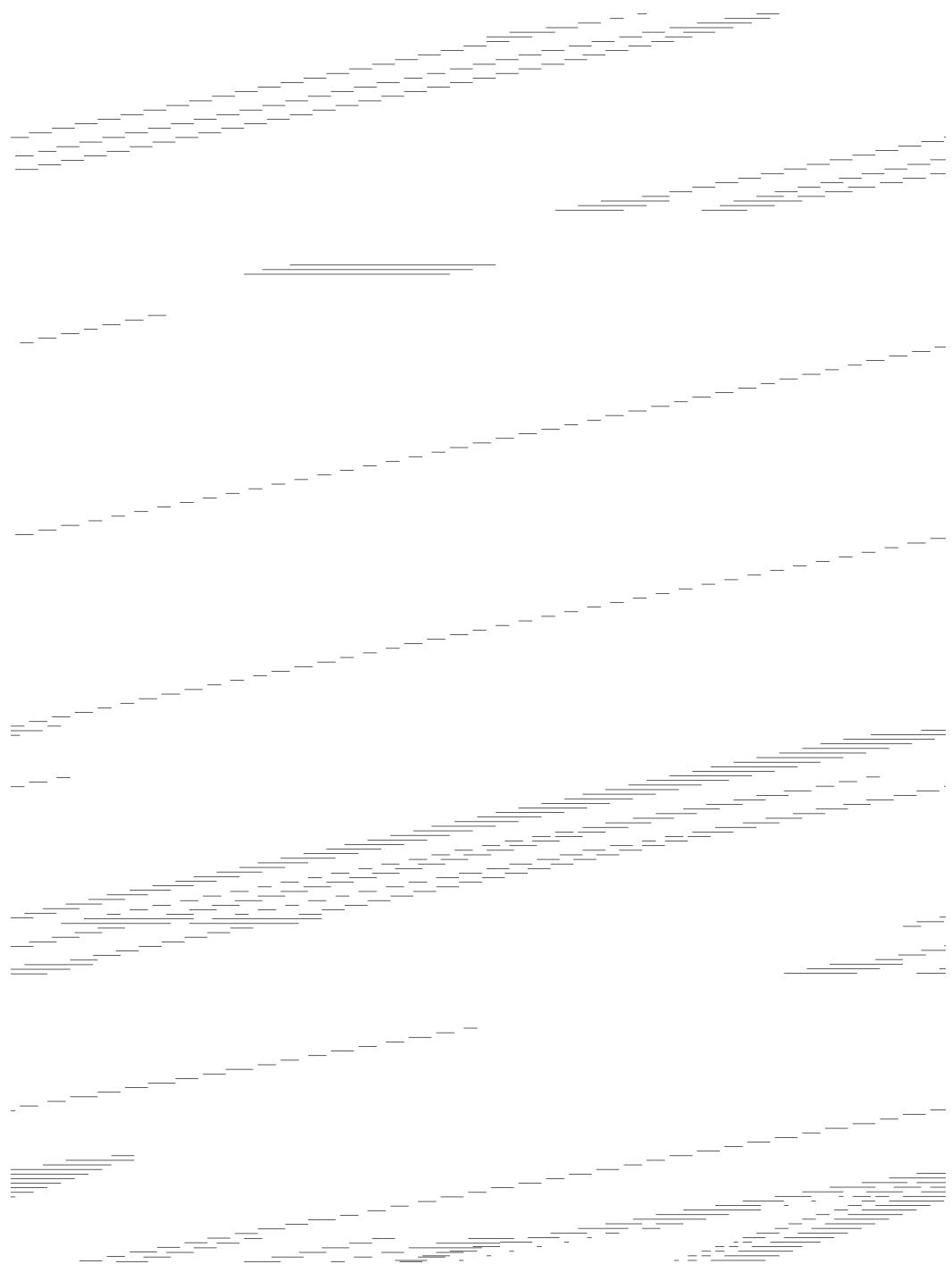


FIG. 1

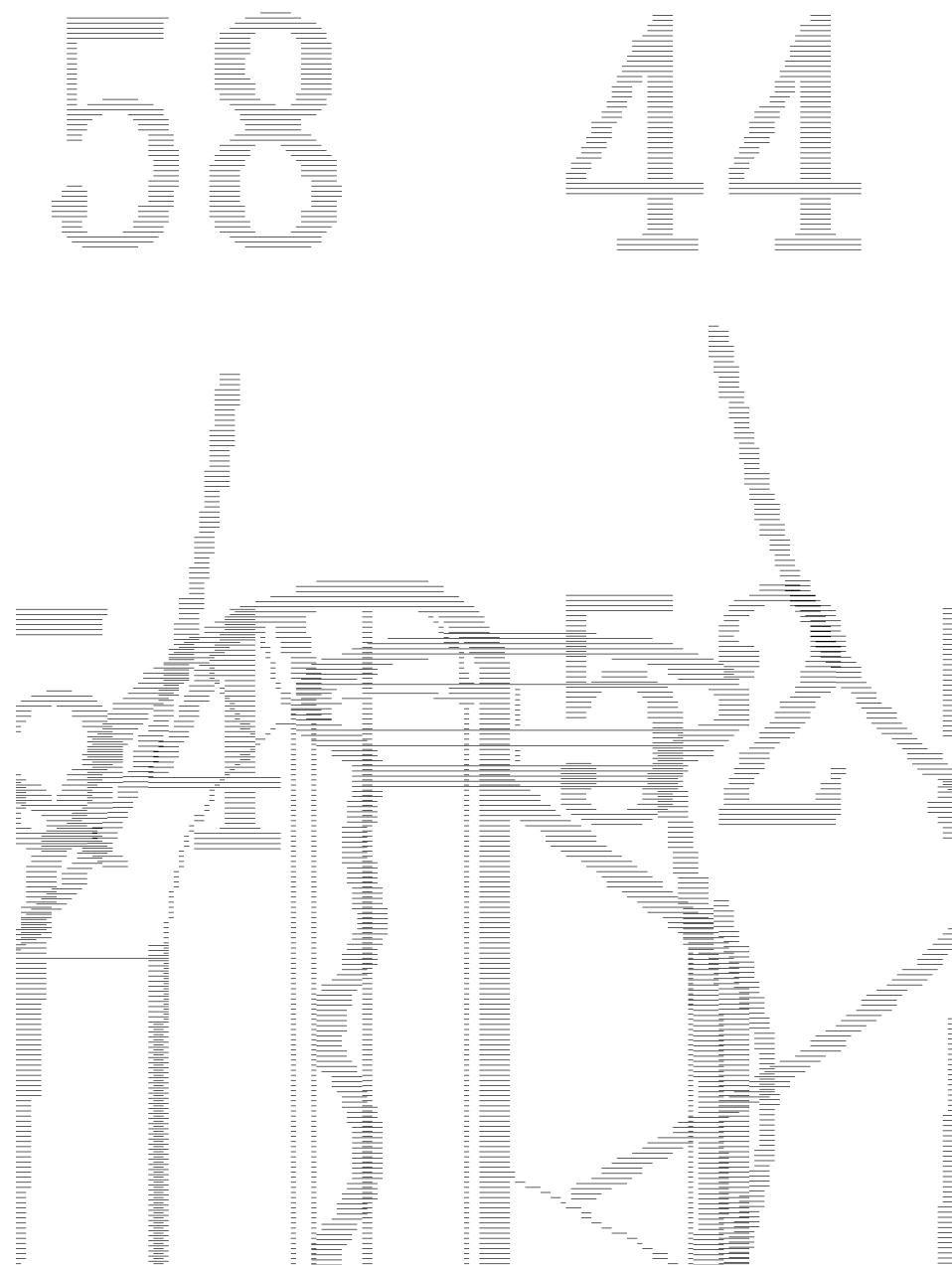


FIG. 2

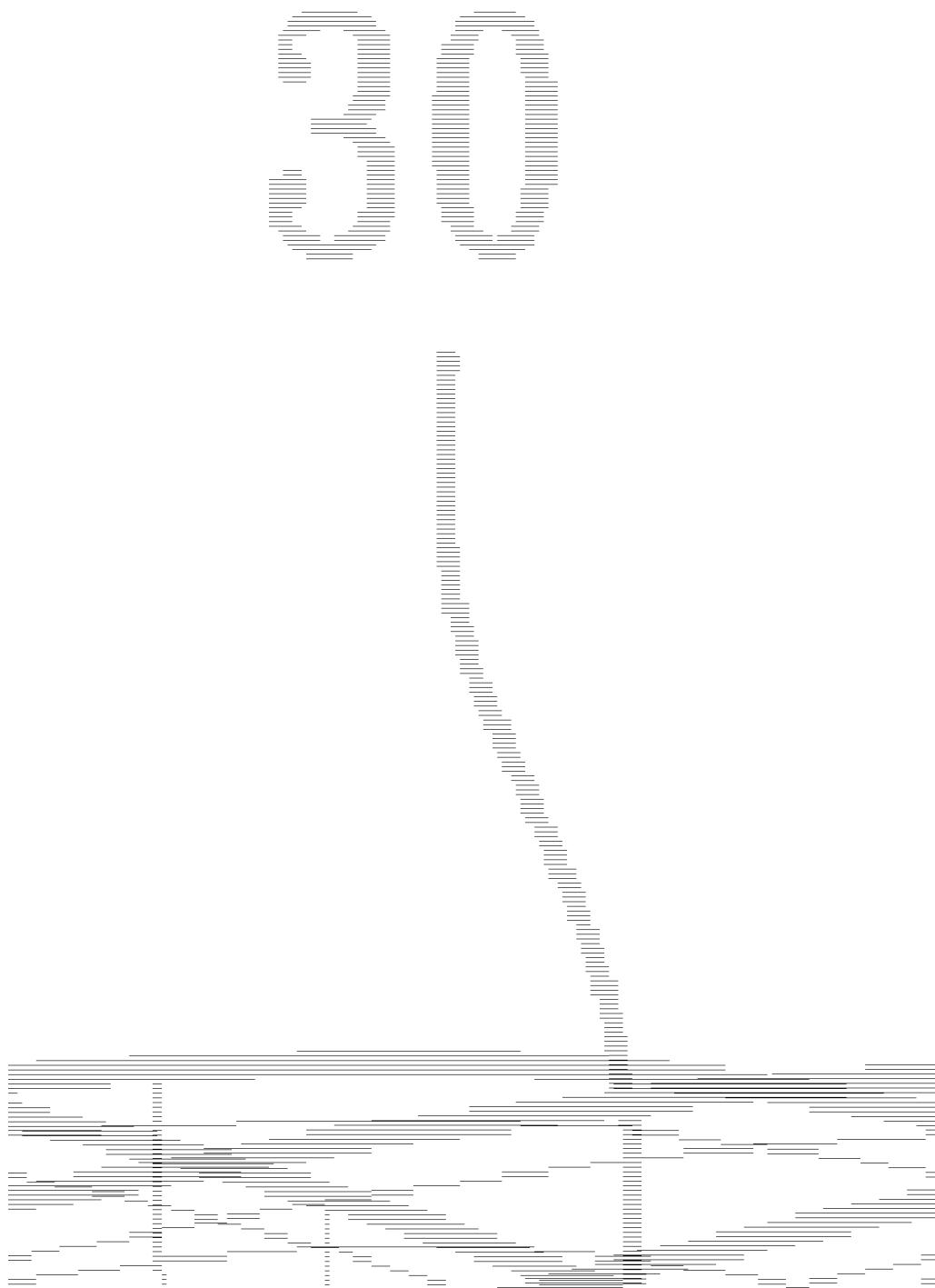


FIG. 3

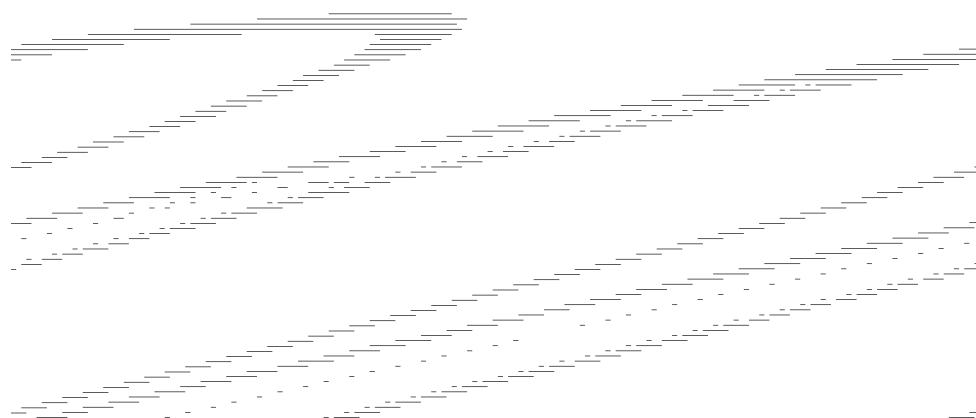
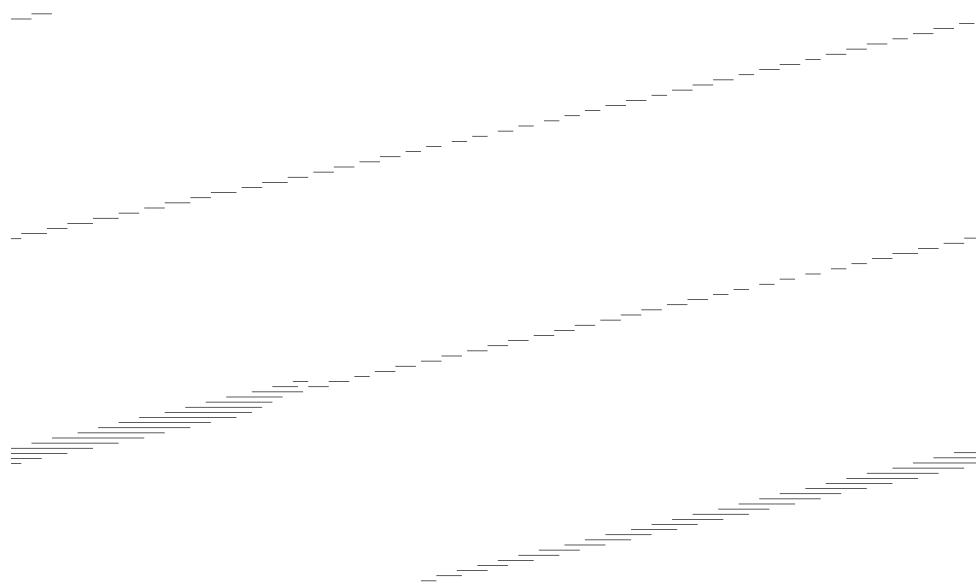
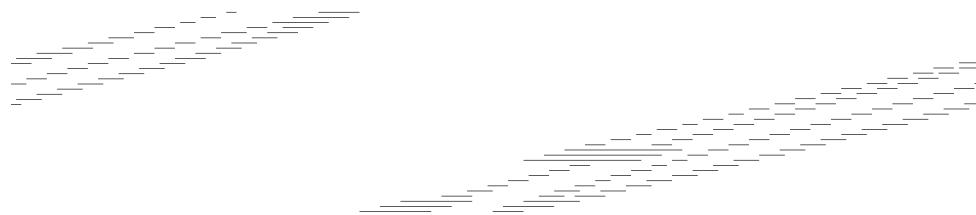


FIG. 4

FIG. 5



FIG. 7

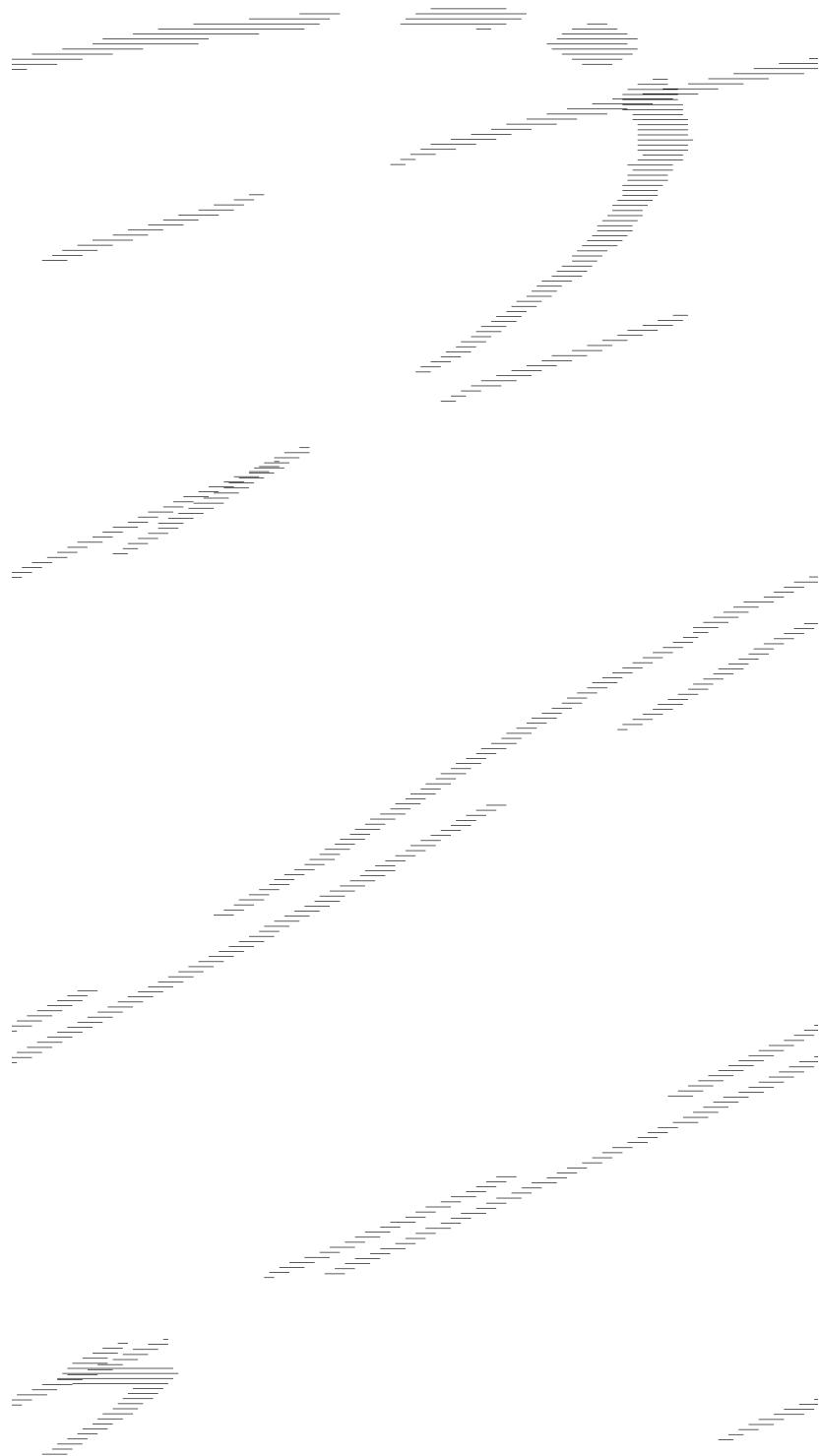


FIG. 8

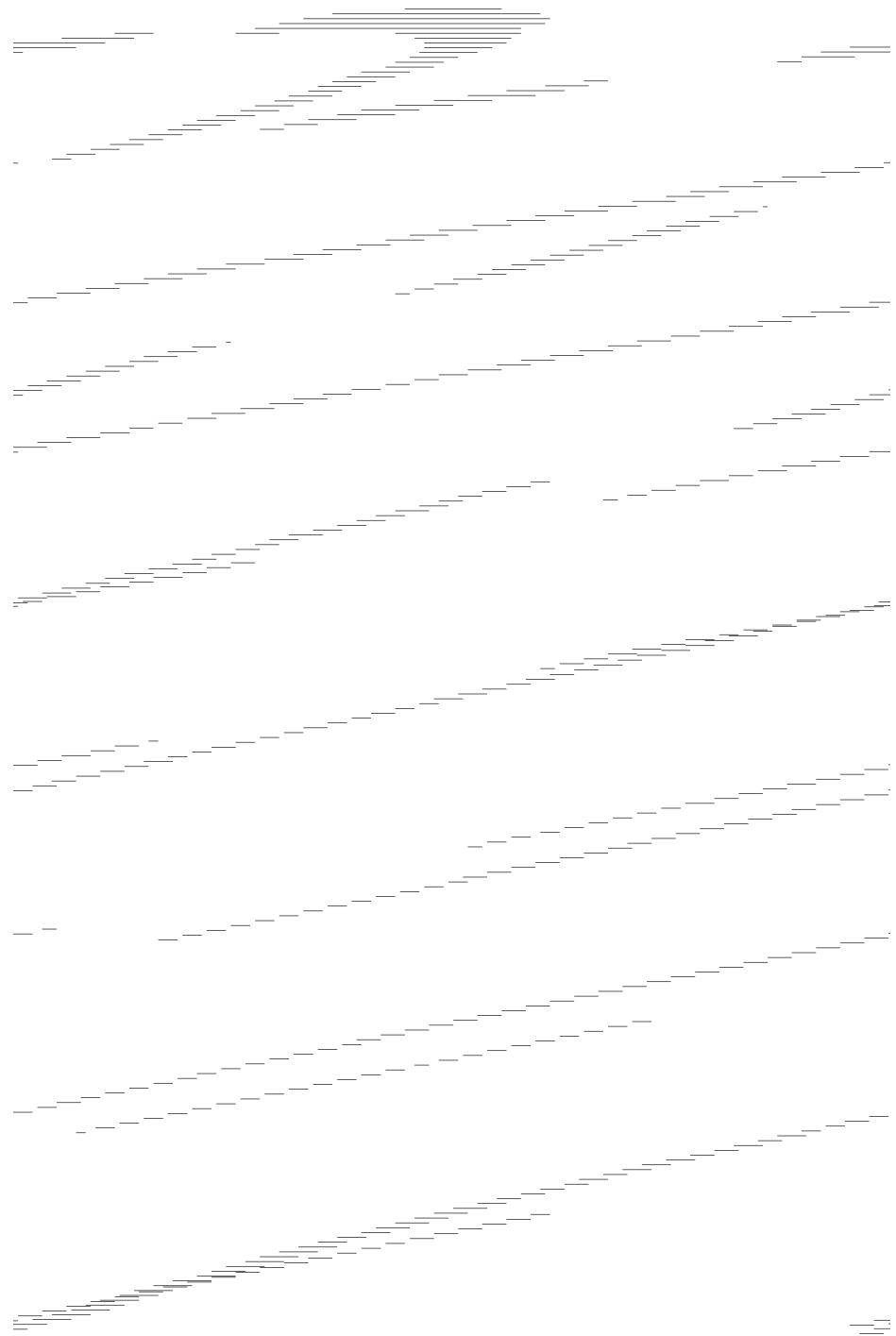


FIG. 9

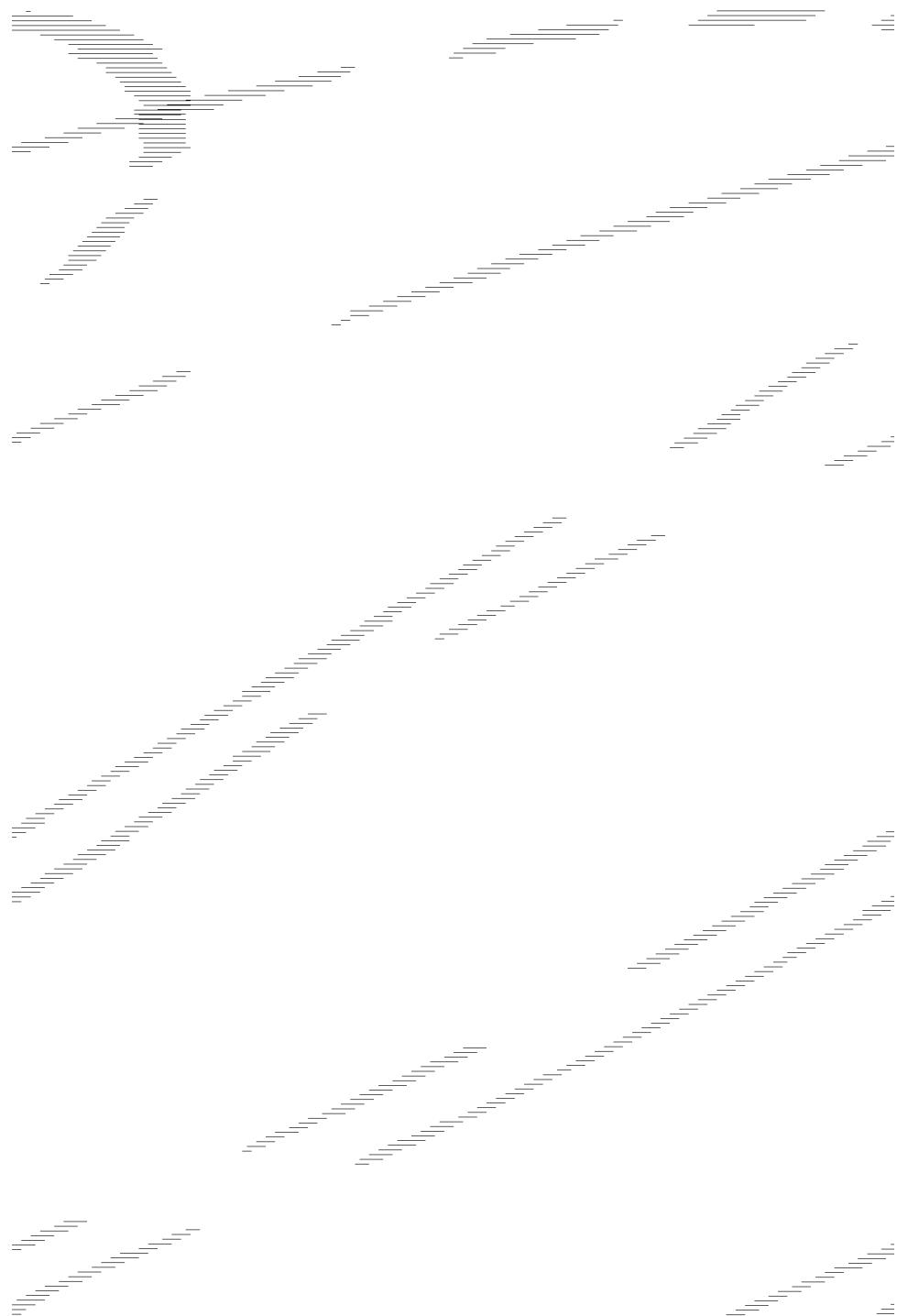


FIG. 11

CORE MUSCLE GROUP TRAINING EQUIPMENT AND ITS METHOD OF USE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to body exercising apparatus and more particularly, to a core muscle group training equipment that provides equal speed muscular strength training and vibration stimulation.

[0003] 2. Description of the Related Art

[0004] The so-called core muscle group are the body's stabilizer muscles between the transverse diaphragm and the pelvis bottom around the waist, abdomen and trunk, including transverse abdominis, lumbar multifidi, internal obliques, external oblique, rectus abdominis, quadrates lumborum, erector spinae, respiratory diaphragm and pvc floor. The core muscle group stabilizes the body trunk, provides sufficient support to the vertebra and distributes the load of the vertebra, facilitating quick movement of the limbs. Neglecting core muscle group training tends to lead to full-body deficiency in motion ability.

[0005] In abdominal muscle training, sit-up is the mostly accepted exercise mode for the advantages of simple action and free site applicability. However, performing sit-up gives a great pressure to the vertebra, thereby tending to cause a vertebral injury. Further, frequently turning the head from a position at a lower elevation relative to the body trunk to a position much higher than the elevation of the body trunk during a sit-up exercise, the exerciser may feel dizzy and experience nausea. More particularly, a hypertension patient may feel uncomfortable when doing sit-ups. Therefore, doing sit-ups is not the best way to train abdominal muscles.

SUMMARY OF THE INVENTION

[0006] The present invention has been accomplished under the circumstances in view. It is the main object of the present invention to provide a core muscle group training equipment, which is practical for training the abdominal muscles and enables the user to keep the head above the elevation of the body trunk during exercise, avoiding discomfort.

[0007] To achieve this and other objects of the present invention, a core muscle group training equipment comprises a seat spaced above the floor at a predetermined elevation, a backrest arranged at the rear side of the seat, and a damping mechanism pivotally coupled to the bottom side of the seat.

[0008] When sitting on the seat and resting the back on the backrest, the user can lift the lower body toward the upper body. By means of biasing of the seat and the damping effect provided by the damping mechanism during operation, the muscle strength of the abdominal muscles is trained.

[0009] Preferably, the core muscle group training equipment further comprises a machine base positioned on the floor and pivotally coupled with the seat and the damping mechanism. Further, the machine base has mounted therein a vibration device adapted for vibrating the seat.

[0010] Preferably, the core muscle group training equipment further comprises two armrests respectively arranged at the left and right sides of the backrest. Each armrest comprises an armrest bar movable forwards and backwards, and a grip located on the front side of the armrest bar.

[0011] To achieve this and other objects of the present invention, a core muscle group training equipment in accordance with an alternate form of the present invention com-

prises a seat spaced above the floor at a predetermined elevation, a backrest arranged at the rear side of the seat and two armrests. Each armrest comprises an armrest frame fixedly connected to one of the opposite left and right sides of said backrest body member, an armrest bar inserted into the armrest frame and movable forward and backward relative to the armrest frame and a grip arranged at the front end of the armrest bar. When sitting on the seat, the user can rest the back on the backrest and the hands on the armrest bars of the armrests, and then bend the upper body forwards and backwards and simultaneously move the armrest bars of the armrest forwards and backwards, thereby training the muscle strength of the abdominal muscles.

[0012] Preferably, each armrest further comprises a damper connected between the respective armrest frame and the rear end of the respective armrest bar. Preferably, the armrest bar of each armrest comprises a plurality of plugholes longitudinally arranged in a line near the front end thereof; the grip of each armrest is selectively plugged into one of the plugholes of the associating armrest bar.

[0013] To achieve this and other objects of the present invention, a core muscle group training equipment in accordance with another alternate form of the present invention comprises a seat spaced above the floor at a predetermined elevation, a support bar vertically arranged at the rear side of the seat, a backrest connected to the top end of the support bar, and a damper connected between the backrest and the top end of the support art. When sitting on the seat and resting the back on the backrest, the user can lift the legs of the lower body toward the upper body to train the muscle strength of the abdominal muscles, and at the same time, the damper provides a damping effect to buffer the backrest.

[0014] Preferably, the core muscle group training equipment further comprises a machine base positioned on the floor and pivotally coupled with the damper. The machine base has a vibration device mounted therein and adapted to vibrate the seat.

[0015] Preferably, a damping mechanism is provided at the bottom side of the seat to provide a damping effect to the seat.

[0016] Other advantages and features of the present invention will be fully understood by reference to the following specification in conjunction with the accompanying drawings, in which like reference signs denote like components of structure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1 is an elevational view of a core muscle group training equipment in accordance with the present invention.

[0018] FIG. 2 is a side view of the core muscle group training equipment in accordance with the present invention.

[0019] FIG. 3 is a sectional side view of a part of the present invention, illustrating the internal structure of the machine base of the core muscle group training equipment.

[0020] FIG. 4 is a sectional side view of the backrest of the core muscle group training equipment in accordance with the present invention.

[0021] FIG. 5 corresponds to FIG. 4, illustrating the backrest body member lowered with the respective damper relative to the support bar.

[0022] FIG. 6 is a sectional side view of one armrest of the core muscle group training equipment in accordance with the present invention.

[0023] FIG. 7 corresponds to FIG. 6, illustrating the armrest bar moved forwards relative to the armrest frame.

[0024] FIG. 8 is a schematic applied view of the core muscle group training equipment in accordance with the present invention (I).

[0025] FIG. 9 is a schematic applied view of the core muscle group training equipment in accordance with the present invention (II).

[0026] FIG. 10 is a schematic applied view of the core muscle group training equipment in accordance with the present invention (III).

[0027] FIG. 11 is a schematic applied view of the core muscle group training equipment in accordance with the present invention (IV).

DETAILED DESCRIPTION OF THE INVENTION

[0028] Referring to FIGS. 1 and 2, a core muscle group training equipment 10 in accordance with the present invention is shown comprising a machine base 20, a seat 30, a backrest 40, two armrests 50 and a damping mechanism 60.

[0029] Referring to FIG. 3, the machine base 20 comprises a housing 22, and a vibration device 24 mounted inside the housing 22. The vibration device 24 comprises a power drive 242, a wheel 244 coupled to and rotatable by the power drive 242 and having a raised portion 248 eccentrically located on the top wall thereof, and a bearing plate 246 supported on the raised portion 248 of the wheel 244 and vibratable by the raised portion 248 during rotation of the wheel 244.

[0030] Referring to FIG. 3 again, the seat 30 is disposed at the top side of the machine base 20 and coupled to the machine base 20 by a linkage 32, having a transverse stop member 302 suspending in the front bottom side thereof. The linkage 32 comprises a pair of links 34 and a transverse rod (not shown). The links 32 have the opposing top and bottom ends thereof respectively pivotally coupled to the seat 30 and the bearing plate 246 of the vibration device 24. The transverse rod is connected between the links 34. Thus, the vibration force produced by the bearing plate 246 of the vibration device 24 can be transferred by the linkage 32 to the seat 30 to cause a synchronous vibration.

[0031] Referring to FIGS. 4 and 5 and FIGS. 1 and 2 again, the backrest 40 comprises a support bar 42, a backrest body member 44 and a damper 46. The support bar 42 has its bottom end connected to the housing 22 of the machine base 20. The backrest body member 44 is coupled to the top end of the support bar 42 and movable up and down relative to the support bar 42, having an accommodation groove 442 located on the middle of the front wall thereof and adapted for accommodating the lumbar spine area of the user's back. The damper 46 consists of a hydraulic cylinder 47 and a spring member 48. The hydraulic cylinder 47 comprises a cylinder body 472 affixed to the backrest body member 44, and a piston rod 474 movable in and out of the cylinder body 472 and coupled with the free end thereof to the top end of the support bar 42. Thus, the hydraulic cylinder 47 imparts a damping resistance to the backrest body member 44 when the backrest body member 44 is being moved downwards relative to the support bar 42 by an external force. As shown in FIGS. 4 and 5, the spring member 48 is sleeved onto the piston rod 474 of the hydraulic cylinder 47 and stopped with its two distal ends against the cylinder body 472 of the hydraulic cylinder 47 and the free end of the piston rod 474 respectively for imparting a return force to the backrest body member 44.

[0032] Referring to FIG. 6 and FIGS. 1 and 2 again, each armrest 50 comprises an armrest frame 52, an armrest bar 54, a damper 56 and a grip 58. The armrest frame 52 is fixedly

connected to one of the opposite left and right sides of the backrest body member 44 and extending forwardly relative to the seat 30. The armrest bar 54 is inserted with its rear end into the armrest frame 52 and movable forward and backward relative to the armrest frame 52, having a plurality of plugholes 542 longitudinally arranged in a line near the front end thereof. The structure of the damper 56 is same as the damper 46 of the backrest 40, and therefore no further structural description is necessary. The damper 56 is connected between the armrest frame 52 and the rear end of the armrest bar 54 so that the armrest bar 54 can be buffered by the damping resistance of the hydraulic cylinder 562 and the spring force of the spring member 564. The grip 58 is selectively insertable with its bottom end into one of the plughole 542 for holding by different user having different body sizes.

[0033] Referring to FIG. 3, the damping mechanism 60 comprises two pairs of dampers 62. The dampers 62 have the same structure as the damper 46 of the backrest 40, and therefore no further structural description is necessary. One pair of dampers 56 are pivotally connected between the seat 30 and the transverse rod of the linkage 32. The other pair of dampers 56 is pivotally connected between the links 34 of the linkage 32 and the bearing plate 246 of the vibration device 24. Thus, the dampers 56 provide a damping effect to the seat 30 during biasing of the seat 30.

[0034] After understanding the structural details of the core muscle group training equipment 10, the method of use and characteristics of the core muscle group training equipment 10 are outlined hereinafter.

[0035] Step a): Sit with the hips on the seat 30 and lie the back on the backrest body member 44 to let the lumbar spine area of the back be rested in the accommodation groove 442 of the backrest body member 44 and to keep the upper body erect, and then hold the position adjusted grips 58 with the two hands and stop the insteps of the legs against the transverse stop member 302 of the seat 30, as shown in FIG. 8.

[0036] Step b): Move one of the upper body and the lower body toward the other of the upper body and the lower body to contract the abdominal muscles, thereby training the muscle strength of the abdominal muscles.

[0037] When performing Step b), the user can keep the lower body immobile and bend the upper body alternatively forwards and backwards. At this time, the user can move the armrest bars 54, stabilizing the forward bending action and keeping the lumbar spine straight, as shown in FIG. 8. Thereafter, the damper 56 of each armrest 50 provides a buffer effect when the user is bending the upper body backwards, and one exercising cycle is completed when the user rests the back on the backrest body member 44 and keeps the upper body erect, as shown in FIG. 10. Thus, a user with an endomorph body type can effectively train the muscle strength of the upper abdominal muscles by repeating this forward and backward bending action.

[0038] On the other hand, a user can keep the upper body immobile and move the lower body alternatively up and down. When the user lifts the lower body, the seat 30 will be biased subject to the downward pressure from the user's hips and the pressure from the insteps of the users legs that are stopped against the transverse stop member 302 of the seat 30, and the damping mechanism 60 will be stretched during biasing of the seat 30, as shown in FIG. 11. At the same time, the backrest body member 44 will be forced by the pressure from the user's back to compress the damper 46 of the backrest 40, as shown in FIG. 5. When the user is lowering the legs,

the seat **30** will be returned to its former position by the return force of the damping mechanism **60**, and the backrest body member **44** will be moved gradually upwardly to its former position by the return force of the damper **46** of the backrest **40**, as shown in FIG. 4 and FIG. 8. Thus, repeating this action effectively trains the muscle strength of the lower abdominal muscles.

[0039] When wishing to increase the training intensity, the user can exercise the aforesaid two actions to train the upper and lower abdominal muscles. During the aforesaid two exercise actions, the vibration force produced by the bearing plate **246** of the vibration device **24** is transferred by the linkage **32** to the seat **30** to activate the user's abdominal muscles. Further, subject to the damping effects of the dampers **46**, vibration stimulation can simply be transferred to the user's abdomen and will not be transferred to the user's head, avoiding user discomfort.

[0040] In conclusion, the core muscle group training equipment of the present invention enables the user to train the muscle strength of the abdominal muscles in a sitting position and to keep the head above the elevation of the body trunk, and therefore a person suffering hypertension will not feel uncomfortable when operating the core muscle group training equipment to train the core muscles, or a person suffering hypotension will not feel faint easily when using the core muscle group training equipment. Further, the damping effects of the dampers used in the core muscle group training equipment provide sufficient buffer, preventing lumbar spine or muscle injury due to a quick return action and assuring a high level of protection. Further, the damping force of every damper is adjustable subject to the muscle strength of every individual user, and therefore the core muscle group training equipment fits different users.

[0041] Although a particular embodiment of the invention has been described in detail for purposes of illustration, various modifications and enhancements may be made without departing from the spirit and scope of the invention. Accordingly, the invention is not to be limited except as by the appended claims.

What is claimed is:

1. A core muscle group training equipment, comprising:
a seat spaced above the floor at a predetermined elevation;
a backrest arranged at a rear side of said seat; and
a damping mechanism pivotally coupled to a bottom side
of said seat.

2. The core muscle group training equipment as claimed in claim 1, further comprising a machine base positioned on the floor to pivotally support said seat and said damping mechanism.

3. The core muscle group training equipment as claimed in claim 2, further comprising a linkage coupled between said seat and said machine base.

4. The core muscle group training equipment as claimed in claim 3, wherein said damping mechanism comprises at least one first damper pivotally coupled between said seat and said linkage and one second damper pivotally coupled between said linkage and said machine base.

5. The core muscle group training equipment as claimed in claim 3, wherein said machine base comprises a housing positioned on the floor and a vibration device mounted inside said housing and pivotally connected with said linkage and said damping mechanism and adapted to provide a vibration force to said seat.

6. The core muscle group training equipment as claimed in claim 5, wherein said vibration device comprises a power drive, a wheel coupled to and rotatable by said power drive, said wheel comprising a raised portion eccentrically located on a top wall thereof, and a bearing plate supported on said raised portion of said wheel and vibratable by said raised portion during rotation of said wheel.

7. The core muscle group training equipment as claimed in claim 2, wherein said backrest comprises a backrest body member and a support bar extended from said backrest body member and connected to said machine base.

8. The core muscle group training equipment as claimed in claim 7, wherein said backrest further comprises a damper connected between said backrest body member and a top end of said support bar.

9. The core muscle group training equipment as claimed in claim 1, further comprising two armrests respectively arranged at opposing left and right sides of said backrest.

10. The core muscle group training equipment as claimed in claim 9, wherein each said armrest comprises an armrest frame fixedly connected to one of the opposite left and right sides of said backrest body member, an armrest bar inserted into said armrest frame and movable forward and backward relative to said armrest frame and a grip arranged at a front end of said armrest bar.

11. The core muscle group training equipment as claimed in claim 1, wherein each said armrest further comprises a damper connected between said armrest frame and a rear end of said armrest bar.

12. The core muscle group training equipment as claimed in claim 10, wherein the armrest bar of each said armrest comprises a plurality of plugholes longitudinally arranged in a line near the front end thereof; the grip of each said armrest is selectively plugged into one of the plugholes of the associating armrest bar.

13. The core muscle group training equipment as claimed in claim 1, wherein said backrest comprises an accommodation groove located on a middle part of a front wall of a backrest body member thereof and adapted for accommodating the lumbar spine area of the back of the user.

14. The core muscle group training equipment as claimed in claim 1, wherein said seat further comprises a transverse stop member suspending in a front bottom side thereof for stopping the insteps of the legs of the user.

15. A core muscle group training equipment, comprising:
a seat spaced above the floor at a predetermined elevation;
a backrest arranged at a rear side of said seat; and
two armrests respectively arranged at opposing left and right sides of said backrest, each said armrest comprising an armrest frame fixedly connected to one of the opposite left and right sides of said backrest body member, an armrest bar inserted into said armrest frame and movable forward and backward relative to said armrest frame and a grip arranged at a front end of said armrest bar.

16. The core muscle group training equipment as claimed in claim 15, wherein each said armrest further comprises a damper connected between said armrest frame and a rear end of said armrest bar.

17. The core muscle group training equipment as claimed in claim 15, wherein the armrest bar of each said armrest comprises a plurality of plugholes longitudinally arranged in

a line near the front end thereof; the grip of each said armrest is selectively plugged into one of the plugholes of the associating armrest bar.

18. The core muscle group training equipment as claimed in claim **15**, further comprising a machine base positioned on the floor and a linkage coupled between said seat and said machine base.

19. The core muscle group training equipment as claimed in claim **15**, wherein said linkage has two distal ends thereof respectively pivotally connected said machine base and said seat.

20. The core muscle group training equipment as claimed in claim **19**, further comprising a damping mechanism pivotally coupled with said seat, said linkage and said machine base.

21. The core muscle group training equipment as claimed in claim **20**, wherein said machine base comprises a housing positioned on the floor and a vibration device mounted inside said housing and pivotally connected with said linkage and said damping mechanism and adapted to provide a vibration force to said seat.

22. The core muscle group training equipment as claimed in claim **20**, wherein said damping mechanism comprises at least one first damper pivotally coupled between said seat and said linkage and one second damper pivotally coupled between said linkage and said machine base.

23. The core muscle group training equipment as claimed in claim **18**, wherein said backrest comprises a backrest body member and a support bar extended from said backrest body member and connected to said machine base.

24. The core muscle group training equipment as claimed in claim **23**, wherein said backrest further comprises a damper connected between said backrest body member and a top end of said support bar.

25. The core muscle group training equipment as claimed in claim **15**, wherein said backrest comprises an accommodation groove located on a middle part of a front wall of a backrest body member thereof and adapted for accommodating the lumbar spine area of the back of the user.

26. The core muscle group training equipment as claimed in claim **15**, wherein said seat further comprises a transverse stop member suspending in a front bottom side thereof for stopping the insteps of the legs of the user.

27. A core muscle group training equipment, comprising: a seat spaced above the floor at a predetermined elevation; a support bar vertically arranged at a back side of said seat; a backrest connected to a top end of said support bar; and a damper connected between said backrest and the top end of said support bar.

28. The core muscle group training equipment as claimed in claim **27**, further comprising a damping mechanism pivotally coupled to a bottom side of said seat.

29. The core muscle group training equipment as claimed in claim **28**, further comprising a machine base positioned on the floor and pivotally coupled with said seat and said damping mechanism.

30. The core muscle group training equipment as claimed in claim **29**, further comprising a linkage coupled between said seat and said machine base.

31. The core muscle group training equipment as claimed in claim **30**, wherein said damping mechanism comprises at least one first damper pivotally coupled between said seat and

said linkage and one second damper pivotally coupled between said linkage and said machine base.

32. The core muscle group training equipment as claimed in claim **30**, wherein said machine base comprises a housing positioned on the floor and a vibration device mounted inside said housing and pivotally connected with said linkage and said damping mechanism and adapted to provide a vibration force to said seat.

33. The core muscle group training equipment as claimed in claim **32**, wherein said vibration device comprises a power drive, a wheel coupled to and rotatable by said power drive, said wheel comprising a raised portion eccentrically located on a top wall thereof, and a bearing plate supported on said raised portion of said wheel and vibratable by said raised portion during rotation of said wheel.

34. The core muscle group training equipment as claimed in claim **27**, wherein said backrest comprises an accommodation groove located on a middle part of a front wall of a backrest body member thereof and adapted for accommodating the lumbar spine area of the back of the user.

35. The core muscle group training equipment as claimed in claim **27**, wherein said seat comprises a transverse stop member suspending in a front bottom side thereof for stopping the insteps of the legs of the user.

36. The core muscle group training equipment as claimed in claim **27**, further comprising two armrests respectively arranged at opposing left and right sides of said backrest.

37. The core muscle group training equipment as claimed in claim **36**, wherein each said armrest comprising an armrest frame fixedly connected to one of the opposite left and right sides of said backrest body member, an armrest bar inserted into said armrest frame and movable forward and backward relative to said armrest frame and a grip arranged at a front end of said armrest bar.

38. The core muscle group training equipment as claimed in claim **37**, wherein each said armrest further comprises a damper connected between said armrest frame and a rear end of said armrest bar.

39. The core muscle group training equipment as claimed in claim **37**, wherein the armrest bar of each said armrest comprises a plurality of plugholes longitudinally arranged in a line near the front end thereof; the grip of each said armrest is selectively plugged into one of the plugholes of the associating armrest bar.

40. A method for operating a core muscle group training equipment as claimed in claim **1**, comprising the steps of:

- a) sitting with the hips on said seat and lying the back on said backrest to keep the upper body erect; and
- b): moving one of the upper body and the lower body toward the other of the upper body and the lower body to contract the abdominal muscles, thereby training the muscle strength of the abdominal muscles.

41. The method as claimed in claim **40**, wherein step b) is to keep the lower body immovable and to bend the upper body forwards and backwards.

42. The method as claimed in claim **40**, wherein step b) is to keep the upper body straightly immovable and to move the legs up and down and at the same time to bias said seat with the hips and to receive a damping resistance from said damping mechanism.