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**Description****TECHNICAL FIELD**

**[0001]** The present invention is directed to medical diagnostic instrumentation. The present invention is also directed to systems for evaluating soft-tissue-injury using surface electromyography.

**BACKGROUND**

**[0002]** Diagnosing soft-tissue injuries (e.g., injury to tissues that connect, support or surround structures and organs of the body including, for example, muscles, tendons, ligaments, fascia, nerves, fibrous tissue, fat, blood vessels, synovial tissues, and the like), as well as assessing pain associated with soft-tissue injury, may be difficult. Soft tissue injuries are often not viewable by the naked eye. Additionally, soft-tissue injury may be difficult (and expensive) to assess even with medical imaging techniques, such as magnetic resonance imagine, computed tomography, ultrasound, and the like.

**[0003]** Examples of systems using electromyographic (EMG) sensors can be found in US2007/0167859, US2005/0075578, EP 1516587 and WO01/37728.

**[0004]** The present invention provides a static surface electromyography ("sEMG") scanner as set out in claim 1 and dependent claims 2-15.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**[0005]** Non-limiting and non-exhaustive embodiments of the present invention are described with reference to the following drawings. In the drawings, like reference numerals refer to like parts throughout the various figures unless otherwise specified.

**[0006]** For a better understanding of the present invention, reference will be made to the following Detailed Description, which is to be read in association with the accompanying drawings, wherein:

FIG. 1 is a schematic perspective view of the one embodiment of a soft-tissue-injury diagnostic system, according to the invention;

FIG. 2 is a schematic perspective view of another embodiment of the soft-tissue-injury diagnostic system shown in FIG. 1, according to the invention;

FIG. 3 is a schematic perspective view of one embodiment of a hub of the soft-tissue-injury diagnostic system shown in FIG. 1, according to the invention;

FIG. 4 is a schematic front view of one embodiment of inclinometers of the soft-tissue-injury diagnostic system shown in FIG. 1, the inclinometers including a main unit and an auxiliary unit, according to the invention;

FIG. 5 is a schematic view of one embodiment of the inclinometers shown in FIG. 4 being used by a user to perform an ROM test on a patient, according to the invention;

FIG. 6 is a schematic view of an exemplary result for an ROM test performed on a patient and displayable on a visual display;

FIG. 7 is a schematic front view of an sEMG module of the soft-tissue-injury diagnostic system shown in FIG. 1;

FIG. 8 is a schematic view of the dynamic sEMG module shown in FIG. 7 coupled to a patient via measuring electrodes while a dynamic sEMG test is performed on the patient;

FIG. 9 is a schematic view of an exemplary result of a dynamic sEMG test performed on a patient;

FIG. 10 is a schematic view of the inclinometers shown in FIG. 4 and the dynamic sEMG module shown in FIG. 7 being used to concurrently perform an ROM test and a dynamic sEMG test on a patient;

FIG. 11 is a schematic view of an exemplary result for an ROM test and a dynamic sEMG test performed concurrently on a patient and displayable together on a visual display;

FIG. 12 is a schematic top view of an exemplary testing arrangement for capturing one or more static images or videos of a patient undergoing an ROM test or a dynamic sEMG test or both tests concurrently;

FIG. 13 is a schematic perspective view of one embodiment of a set of hand-held static sEMG scanners of the soft-tissue-injury diagnostic system shown in FIG. 1, according to the invention;

FIG. 14A is a schematic perspective view of one embodiment of one of the static sEMG scanners of FIG. 13 with a ground in an extended position and a portion of an outer casing of the static sEMG scanner removed, according to the invention;

FIG. 14B is a schematic perspective view of one embodiment of one of the static sEMG scanners shown in FIG. 13 with a ground in a retracted position and a portion of an outer casing of the static sEMG scanner removed, according to the invention;

FIG. 15 is a schematic side view of one embodiment of one of the static sEMG scanners shown in FIG. 13 positioned against a patient such that the measuring electrodes are individually pivoted according patient contours, according to the invention;

FIG. 16 is a schematic view of one embodiment of the static sEMG scanners shown in FIG. 13 being used by a user to perform a static sEMG test on a patient, according to the invention;

FIG. 17 is a schematic view of two exemplary results from a static sEMG test performed on a patient;

FIG. 18 is a schematic perspective view of a mountable static sEMG scanner of the soft-tissue-injury diagnostic system shown in FIG. 1;

FIG. 19 is a schematic side view of a measuring electrode of the static sEMG scanner shown in FIG. 18;

FIG. 20 is a schematic view of a set of four measuring electrodes of the static sEMG scanner shown in FIG. 18 in two positions, the second position horizontally pivoted from the first position;

FIG. 21 is a schematic rear view of the static sEMG scanner shown in FIG. 18 aligned against a back of a human figure; and

FIG. 22 is a schematic top view of an exemplary testing arrangement for capturing one or more images or videos of a patient while undergoing a static sEMG test.

#### DETAILED DESCRIPTION

**[0007]** The present invention is directed to medical diagnostic instrumentation. The present invention is also directed to systems for evaluating soft-tissue-injury using surface electromyography.

**[0008]** The systems, and devices described herein may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Accordingly, the systems, and devices described herein may take the form of an entirely hardware embodiment, an entirely software embodiment or an embodiments combining software and hardware aspects. The methods described herein, which do not form part of the claimed subject-matter, can be performed using any type of computing device, such as a computer, that includes a processor or any combination of computing devices where each device performs at least part of the process.

**[0009]** Suitable computing devices typically include mass memory and typically include communication between devices. The mass memory illustrates a type of computer-readable media, namely computer storage media. Computer storage media may include volatile, nonvolatile, removable, and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, program modules, or other data. Examples of computer storage media include RAM, ROM, EEPROM, flash memory, or other memory technology, CD-

ROM, digital versatile disks ("DVD") or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by a computing device.

**[0010]** Methods of communication between devices or components of a system can include both wired and wireless (e.g., RF, optical, or infrared) communications methods and such methods provide another type of computer readable media; namely communication media. Communication media typically embodies computer-readable instructions, data structures, program modules, or other data in a modulated data signal such as a carrier wave, data signal, or other transport mechanism and include any information delivery media. The terms "modulated data signal," and "carrier-wave signal" includes a signal that has one or more of its characteristics set or changed in such a manner as to encode information, instructions, data, and the like, in the signal. By way of example, communication media includes wired media such as twisted pair, coaxial cable, fiber optics, wave guides, and other wired media and wireless media such as acoustic, RF, infrared, and other wireless media.

**[0011]** Over the years, several types of medical diagnostic devices have been developed that measure one or more patient capabilities which may be helpful in evaluating soft-tissue injury. One such type of medical diagnostic device is a surface electromyograph ("sEMG"), which can be used for measuring the muscle tension of selected muscle groups of a patient, either while the patient performs various movements (e.g., a dynamic sEMG) or while a patient is at rest (e.g., a static sEMG). Another such type of medical diagnostic device is a range-of-motion tester ("ROM"), which can be used for measuring how far a patient can bend along a given joint. However, despite advancements in sEMG and ROM technologies, a tool for completely diagnosing soft-tissue injuries and assessing corresponding patient pain remains elusive.

**[0012]** As a result of the inability to reliably diagnose or assess soft-tissue injury, the healthcare system may experience a financial burden by misdiagnosing some types of patient injuries and consequently applying inappropriate therapies. Additionally, the insurance system and the court system may likewise experience a financial burden due to some people falsely claiming (or grossly exaggerating the extent of) soft-tissue injuries in order to receive money or other forms of consideration.

**[0013]** As described below, a soft-tissue-injury diagnostic system ("diagnostic system") may be used to perform one or more diagnostic tests on a patient, either singularly or in combination, including an ROM test, a dynamic sEMG test, and a static sEMG test. The diagnostic system may also include one or more video cameras. Multiple video cameras may be used to capture video (or photographs) of a patient's movements while undergoing one or more of the abovementioned tests. Results from one or more of the tests may be used by

one or more medical practitioners to diagnose or assess soft-tissue injury.

**[0014]** Figure 1 is a schematic perspective view of one embodiment of a diagnostic system 100. The diagnostic system 100 includes inclinometers 102 for performing an ROM test on a patient (testing how far the patient can bend), a hub 104, a dynamic sEMG control module ("sEMG module") 106 for use in performing a dynamic sEMG test on a patient (measuring action potentials along muscle groups as the patient performs various movements), and static sEMG scanners ("scanners") 108 for performing a static sEMG test on a patient (measuring action potentials along muscle groups as the patient maintains a given position).

**[0015]** The inclinometers 102, the dynamic sEMG module 106, and the scanners 108 are in electrical communication with the hub 104. In some embodiments, one or more of the inclinometers 102, the dynamic sEMG module 106, and the scanners 108 are electrically coupled to the hub 104 by a wireless network, such as 3G. In other embodiments, one or more of the inclinometers 102, the dynamic sEMG module 106, and the scanners 108 are electrically coupled to the hub 104 by one or more conductors, such as wires.

**[0016]** The diagnostic system 100 also includes (as shown in Figure 2) one or more processors 202, one or more visual displays 204, and one or more video cameras 206. The hub 104 is electrically coupled to the one or more processors 202. The one or more processors 202 receive and process input data from the inclinometers 102, the dynamic sEMG module 106, or the scanners 108 (via the hub 104) and display the results of the processed data on the one or more visual displays 204. At least a portion of one or more of the ROM test, the dynamic sEMG test, or the static sEMG test are visually captured by the one or more video cameras 206.

**[0017]** The diagnostic system 100 includes software or hardware for facilitating many different operations including, for example, linking the inclinometer 102, the dynamic sEMG module 106, or the scanners 108 to the hub 104, performing the ROM test, the dynamic sEMG, and the static sEMG, displaying the results of the ROM test, the dynamic sEMG, or the static sEMG, saving and backing-up testing data, and powering on or off the testing devices.

**[0018]** Figure 3 is a schematic front view of the hub 104. The hub 104 includes one or more inputs 302 for coupling the inclinometer 102, the dynamic sEMG module 106, or the scanners 108 to the hub 104. The hub 104 also includes inputs 304 for one or more peripherals (e.g., a keyboard, a mouse, a monitor, a printer, a storage device, or the like). The hub 104 includes one or more user interfaces 306 (e.g., displays, keypads, or the like). The hub 104 includes one or more indicators 308, such as a power indicator, connectivity indicator, or the like. Multiple hubs 104 may be utilized, in parallel or in series. The one or more hubs 104 receive and process input data from the inclinometers 102, the dynamic sEMG

module 106, or the scanners 108 and display the results on a display, such as an LCD, coupled to (or disposed on) the hub 104. The one or more hubs 104 include a keypad for inputting information.

**[0019]** Figure 4 is a schematic front view of one embodiment of the inclinometers 102 of the diagnostic system 100. The inclinometers 102 includes a main unit 402 and an auxiliary unit 404. The main unit 402 and the auxiliary unit 404 are each substantially disc-shaped with a coupled flat bottom surface 406 extending tangentially from a bottom portion of the discs. The flat bottom surface 406 includes two or more feet 408. The feet 408 are independently slidable along the flat bottom surface 406 such that the distance between the feet 408 may be adjusted.

**[0020]** The main unit 402 and the auxiliary unit 404 each include a plurality of light-emitting diodes ("LEDs"), such as LEDs 410 positioned on the bodies of the main unit 402 and the auxiliary unit 404 to form degree markings. For example, the LEDs may be positioned to mark 0 degrees, 90 degrees, 180 degrees, and 270 degrees when the main unit 402 or the auxiliary unit 404 is placed in an upright position resting on the flat bottom surface 406. The LEDs may be used by a user to determine a relative angle between the main unit 402 and the auxiliary unit 404 without needing to look at a computer display to obtain this information. The LEDs may be used to mark the degrees of rotation between the main unit 402 and the auxiliary unit 404 based upon gravity.

**[0021]** The main unit 402 and the auxiliary unit 404 use accelerometers. By using the LED degree markings and accelerometers, a user is able to use a true level (bubble-type level) to calibrate the inclinometers 102 to true center of the earth, and then have the ability to show, with LEDs, true zero with respect to gravity.

**[0022]** The LEDs allow a user to see, by looking at the main unit 402 or the auxiliary unit 404, when the main unit 402 or the auxiliary unit 404 is at various degrees from earth center zero gravity. This allows the user to electronically provide a measurement without the use of a manual visual pendulum (which is a technique currently employed by some conventional devices). This may save time, and provide a more accurate reading as the angle data is stored by the hub 104 or the one or more processors 202, and does not require a human to calculate degrees.

**[0023]** One or more LED-flashing systems may be implemented to convey to a user at what angle either the main unit 402 or the auxiliary unit 404 is at during performance of an ROM test. For example, when the LEDs are configured so that one or more LEDs mark 0 degrees, 90 degrees, 180 degrees, and 270 degrees, the LED(s) may provide feedback to the user as follows: when the main unit 402 or the auxiliary unit is at 0 degrees, for example, the one or more LEDs marking 0 degrees emit a green light. When the main unit 402 or the auxiliary unit 404 is rotated to 0 degrees minus 1 degree, the one or more LEDs marking 0 degrees emit a yellow light and

flash at a rate of 1 time per second. When the main unit 402 or the auxiliary unit 404 are rotated to 0 degrees minus 2 degrees, the one or more LEDs marking 0 degrees emit a yellow light and flash at a rate of 2 times per second. This continues on up to 5 degrees. When the main unit 402 or the auxiliary unit 404 are rotated to 0 degrees plus 1 degree, the one or more LEDs marking 0 degrees emit a red light or another color, and will flash with the same frequency as above, increasing at the same rate as the number of degrees increases from zero. So, for example, at 5 degrees, the one or more LEDs marking 0 degrees emit a red light and flash at a rate of 5 times per second.

**[0024]** In other embodiments, the main unit 402 or the auxiliary unit 404 each include 11 LEDs. In at least some embodiments, a plurality of colors are used. For example, the center may include 1 green LED. On either side at 1 degree increments there may be yellow LED's which indicate 1 degree increments under 0 degrees. On the other side of the 1 green LED there may be 5 red (or another color) LEDs which are spaced equally by 1 degree, and light up in order from the 1st to 5th LED indicating 1 to 5 degrees from center (0 degrees in this case). The 1 green LED in the center may emit light when the main unit 402 or the auxiliary unit 404 is held at 0 degrees compared to earth, and as the main unit 402 or the auxiliary unit 404 is moved away from 0 degrees (or any of the major markers (typically 0, 90, 180, 270), with the LED's lighting up in order as the 1-5 degrees is met from center.

**[0025]** Software associated with the ROM test utilizes voice signaling to facilitate operation of the inclinometers 102 or performance of an ROM test. For example, a voice signal may be output, via one or more speakers electrically coupled to the hub 104 or the one or more processors 202, the actual level in degrees in comparison to the center of the earth for one or both of the units 402 and 404 so that a user can focus on holding the main unit 402 or the auxiliary unit 404 against the patient and provide a more accurate reading, without dividing attention to attempt to read the values on a screen or on a mechanical device.

**[0026]** For example, when the main unit 402 or the auxiliary unit 404 is set up so that the top is at 0 degrees (is straight up and down), a voice signal may be emitted that says "zero degrees." In addition, the emitted voice signal may say "plus 1 degree," "plus two degrees," or the like, to mark the movement of the main unit 402 or the auxiliary unit 404 from center position. Voice signaling may be used to provide commands to a user of the inclinometers 102 before, during, or after a ROM test. For example, a voice signal may prompt the user when to instruct a patient to perform a given movement, when to record a marking (discussed below), or the like.

**[0027]** The inclinometers 102 include one or more controllers 412 (e.g., buttons, switches, knobs, or the like) that may be used by a user during an ROM test to record a marking. For example, the user may press a button during an ROM test to record a marking when a patient

is at a neutral position, or when a patient is at a fully-flexed position. The recorded markings may be subsequently used to facilitate interpretation of a display of results from the ROM test. Two controllers 412 are positioned on each of the inclinometers 102. The inclinometers 102 can be operated using either of the two controllers 412.

**[0028]** The inclinometers 102 are powered by one or more batteries. The inclinometers are automatically powered off after a given amount of time has elapsed without being used. The inclinometers 102 are automatically powered off after the associated software has been powered off. The inclinometers 102 are automatically powered off after an ROM test has been completed. The inclinometers 102 include a master power switch which, when in one position, maintain the inclinometers 102 powered off.

**[0029]** The inclinometer 102 is in electrical communication with the hub 104 and data created during the performance of an ROM test are input to the hub 104. The data is processed by the hub 104 (or a plurality of hubs). At least some of the data input to the hub 104 is output to the one or more electrically coupled processors 202 for further processing.

**[0030]** The inclinometers 102 are positioned along a patient body portion that moves along a patient joint at one end of the body portion. The body portion can be any part(s) of the body, such as a limb, extending distally from a joint (e.g., head, neck, finger, hand, arm, forearm, waist, toe, ankle, knee, leg, or the like or combinations thereof). The inclinometers 102 may be positioned such that the main unit 402 is positioned against a patient joint and the auxiliary unit 404 is positioned distally from the joint along the moveable body portion.

**[0031]** Figure 5 is a schematic view of the inclinometers 102 being used to perform an ROM test on a patient 502. In Figure 5, a lateral flexion ROM test is being performed on the patient's cervical spine. It will be understood that this is just one of many different ROM tests that may be performed on a patient 502. In Figure 5, the main unit 402 is positioned at the base of the neck, for example, and the auxiliary unit 404 on top of the head, a difference between the main unit 402 and the auxiliary unit 404 (in degrees compared with zero gravity ground) is measured as the patient moves from a neutral position to a fully-flexed position in a given direction (e.g., laterally flexed). As the patient 502 bends his or her head laterally, the difference between the two units 402 and 404 in degrees (main unit 402 minus auxiliary unit 404) provides the actual number of degrees which the patient 502 has flexed his or her neck. The main unit 402 and the auxiliary unit 404 may, therefore, be used to measure the range of motion as the hub 104 (or one or more coupled processors 202) is able to quickly and accurately measure both the main unit 402 and the auxiliary unit 404 simultaneously to measure the angle of movement. The associated software remains idle until the patient 502 is in a final neutral posture.

**[0032]** The feet 408 on the main unit 402 or the auxiliary unit 404 are adjustable. At least one of the feet 408 slides along an axis separating the feet 408 (e.g., along an axis of the flat bottom surface 406), thereby increasing or decreasing the distance between the feet 408. The adjustable feet 408 may be used to facilitate steady contact being made between the main unit 402 or the auxiliary unit 404 and the patient. For example, it may be the case that measuring the range of motion of one of the patient's fingers is more easily performed when the feet 408 are closer together than when measuring the range of motion of the patient's waist.

**[0033]** The shape of the main unit 402 and the auxiliary unit 404 may also facilitate making steady contact with a patient. A user may place hold of the main unit 402 or the auxiliary unit 404 between two of his or her fingers with his or her palm flat against the patient (as shown in Figure 5) so as to steadily hold the main unit 402 or the auxiliary unit 404 in position while still being able to see the LEDs and use the control buttons 412 during performance of an ROM test.

**[0034]** Figure 6 is a schematic view of an exemplary display 602 for an ROM test performed on the patient 502 and displayable on the one or more visual displays 204. Note that the exemplary display 602 of a ROM test can be displayed in many other different ways on the one or more visual displays 204. The display 602 can be displayed on the hub 104 or other display electrically coupled to the hub 104 in lieu of, or in addition to, the one or more visual displays 204.

**[0035]** Figure 7 is a schematic front view of the dynamic sEMG module 106 of the diagnostic system 100. The dynamic sEMG module 106 is configured and arranged for facilitating the performance of a dynamic sEMG test on a patient. Data collected during performance of the dynamic sEMG test is input to the hub 104 and processed by the hub 104 or by one or more processors 202. The dynamic sEMG module 106 includes a master power switch (not shown) which, when in one position, maintains the dynamic sEMG module 106 powered off.

**[0036]** The dynamic sEMG module 106 is configured and arranged to receive measuring electrodes coupled to a patient. The dynamic sEMG module 106 is configured and arranged to receive up to sixteen measuring electrodes. The measuring electrodes coupled to the dynamic sEMG module 106 may be formed from many different conductive materials suitable for placement against the skin of a patient including, for example, gold, stainless steel, silver, silver chloride, and the like or combinations thereof. Multiple dynamic sEMG modules may be electrically coupled to one another or to the hub 104.

**[0037]** Figure 8 is a schematic view of a patient 802 performing a movement associated with a dynamic sEMG test. In Figure 8, the dynamic sEMG module 106 is coupled to a strap 804 (e.g., a belt, or the like) being worn by the patient 802. Measuring electrodes 806 are attached to the patient 802 and electrically coupled to the dynamic sEMG module 106. The measuring elec-

trodes 806 are positioned at various spinal levels determined by the muscle groups whose activity is to be measured during controlled patient movement. For example, the measuring electrodes 806 may be attached to the back of the patient 802 in lateral proximity to the spine at various spinal levels to measure the size and timing of action potentials as the patient moves in a manner that utilizes the muscles in proximity to the location of the attached measuring electrodes 806. A ground 808 may also be used to couple the patient 802 to the dynamic sEMG module 106.

**[0038]** In Figure 8, the patient 802 has measuring electrodes 806 attached to her back which measure the size and timing of action potentials along selected muscle groups during flexion and extension at her waist. Multiple dynamic sEMG modules 106 (each dynamic sEMG module 106 electrically coupled to multiple different measuring electrodes) may be used to perform multiple concurrent dynamic sEMG tests on a patient. When multiple dynamic sEMG tests are performed on a patient, multiple results may be input to the hub 104.

**[0039]** Figure 9 is a schematic view of an exemplary display 902 of a dynamic sEMG test performed on the patient 802. Note that exemplary display 902 of a dynamic sEMG test can be displayed in many other different ways on the one or more visual displays 204. The exemplary display 902 is displayed on the hub 104 or a visual display electrically coupled to the hub 104.

**[0040]** An ROM test and one or more dynamic sEMG tests may be performed concurrently. Figure 10 is a schematic view of one embodiment of a user 1002 concurrently performing an ROM test and a dynamic sEMG test on a patient 1004. The inclinometers 102 (ROM test) and the measuring electrodes 806 of the dynamic sEMG module 106 (dynamic sEMG test) are shown coupled to the patient 1004. Measuring muscle activity and range of motion concurrently may provide further insight into the nature and extent of patient injury. Data from both the ROM test and the dynamic sEMG test may be combined together in a single graphic display to show the timing, symmetry, and magnitude of the patient's muscle responses during patient movement. Combining an ROM test with a dynamic sEMG test may increase the accuracy of readings and also create results with increased reproducibility from conventional tests.

**[0041]** The data for one or more of the motions from the ROM test may be arranged in a graphic which follows the American Medical Association ("AMA") guides for ROM, such as the pie graph result 602 shown in Figure 6. Currently, the only known method to gather ROM data and generate impairment ratings based upon the AMA guides is to perform the ROM test separately from the dynamic sEMG. By performing the ROM test and dynamic sEMG tests concurrently and generating ROM data in the format required by the AMA guides, time and money may be saved. When ROM data, after a selected number of trials of each motion, is not within the required variability allowed by the AMA guides, the software automati-

ically informs the user that the ROM test is invalid, and may be performed again, thereby potentially saving additional time and money.

**[0042]** Figure 11 is a schematic view of an exemplary visual display 1102 showing results of a concurrently performed ROM test and dynamic sEMG test. In Figure 11, the dynamic sEMG data 1104 is shown graphically on the top half of the visual display 1102 and the ROM data 1106 is shown graphically on the bottom half of the visual display 1102. The dynamic sEMG data 1104 and the ROM data 1106 are shown over time so that muscular activity of selected muscles can be seen visually during a corresponding performance of specific movements by the patient 1004. Timing, symmetry, and magnitude of the patient's muscle responses may be displayed. Such information may correspond with the nature and extent of patient injury.

**[0043]** Further insight into the nature and extent of patient injury may be obtained by further including one or more video cameras, such as video camera 206, to capture one or more static images or, preferably, a video image of the performance of one or more of an ROM test and a dynamic sEMG test. Figure 12 is a schematic top view of an exemplary testing arrangement for capturing one or more images or videos of a patient undergoing an ROM test and a dynamic sEMG test. In Figure 12, three video cameras: 1202, 1204, and 1206, are placed around a mat 1208 that includes points 1210 and 1212 representing points for a patient to stand during performance of the ROM test and the dynamic sEMG test. The video camera 1202 is positioned directly in front of a patient standing on points 1210 and 1212, while the video camera 1204 is positioned directly behind the patient, and while the video camera 1206 is positioned to one side of the patient.

**[0044]** The addition of captured images or videos may be made available for review by one or more medical practitioners. The data from one or more of the ROM test, dynamic sEMG test, and the videos (or static images) may be stored on the hub 104, one or more processors 202, or a storage device, and arranged so that one or more medical practitioners may use a slider to play back the patient's motion (for example, a forward flexion) and determine precisely the angle at which the patient has bent along with video of the patient's body showing the precise manner of movement. Moreover, similar testing may subsequently be performed on the same patient. Thus, comparison of two or more data sets may be performed to provide data for tracking patient progress over time.

**[0045]** The diagnostic system 100 includes scanners 108 for use by a user in administering a static sEMG test on a patient (measuring action potentials along selected muscle groups while the patient maintains a particular position). Sometimes a static sEMG test may involve a series of measurements taken during a set of successive placements of the scanners 108 against patient skin. Figure 13 is a schematic perspective view of one embodiment

of scanners 108 of the diagnostic system 100. The scanners 108 each include a plurality of measuring electrodes 1302 disposed on a front end 1303. The measuring electrodes 1302 are arranged into sets, such as a first measuring electrode set 1304 and a second measuring electrode set 1306. The scanners 108 also include a ground 1308 disposed on the front end 1303.

**[0046]** The scanners 108 are configured and arranged to be hand-held by a user during the performance of a static sEMG test. The scanners 108 each include one or more controllers 1310 (e.g., buttons, switches, knobs, or the like). A user of the scanners 108 may use the controllers 1310 to control progress during a static sEMG test without using a keypad, keyboard, or the like in between successive placements of the measuring electrodes 1304 against patient skin. The scanner 108 includes one or more indicators 1312, such as one or more LEDs, which provide one or more indications to a user (e.g., battery level, on/off, connectivity, or the like) before, during, or after performance of a static sEMG test. The scanners 108 include one or more gripping members (not shown) to facilitate gripping of the scanners 108 by the user 1602 while performing a static sEMG. For example, the scanners 108 may include one or more indentations configured and arranged to facilitate holding of the scanners 108 by the user 1602 during administration of a static sEMG test. Scanners 108 include a master power switch which, when in one position, maintain the scanners 108 powered off.

**[0047]** The sets of measuring electrodes 1302 each include two electrodes, such as measuring electrodes 1304a and 1304b of the first measuring electrode set 1304. The measuring electrodes within a set of measuring electrodes are horizontally spaced apart from one another on the front end 1303. The sets of measuring electrodes are vertically spaced apart from one another. The ground 1308 can be disposed anywhere on the front end 108. The ground 1308 is positioned vertically between the measuring electrode sets 1304 and 1306. The ground 1308 is positioned horizontally between individual measuring electrodes within a set of measuring electrodes 1302.

**[0048]** Each set of measuring electrodes 1302 corresponds to a spinal level. Thus, the number of sets of measuring electrodes 1302 disposed on the scanner 108 may correspond to the number of spinal levels that can be simultaneously measured. A user may place the measuring electrodes 1302 of the scanners 108 against a back of a patient in lateral proximity to the patient's spine at a desired level to measure action potentials. The scanners 108 shown in Figure 13 can be used to measure two spinal levels at a time for each placement of the scanners 108 against the patient, for example Cervical level 2 ("C2") and Cervical level 4 ("C4").

**[0049]** Any number of sets of measuring electrodes may be disposed on the scanner 108 including, for example, one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen, sixteen,

seventeen, eighteen, nineteen, twenty, twenty-one, twenty-two, twenty-three, twenty-four, or more sets of measuring electrodes. It will be understood that additional sets of measuring electrodes may be disposed on the scanner 108, as well.

**[0050]** The scanners 108 communicate with the hub 104 (and, optionally, one or more processors 202, via the hub 104). In at least some embodiments, the scanners 108 are wireless. When the scanners 108 are wireless, a user and patient are not limited to either being positioned in the immediate vicinity of the hub 104 or creating a potential hazard by extending one or more conductors over a space where the conductors may present a hazard, such as potentially being tripped over. Consequently, wireless scanners 108 may be used, for example, at a screening (where a user is at a mall, health fair, car show, or the like) to go out into a crowd to test people without needing to entice people into a testing center. The results of a static sEMG test may be shown in real-time on one or more visual displays 204. In at least some embodiments, data from a static sEMG may be transmitted at least thirty feet to the hub 104.

**[0051]** The diagnostic system 100 may include multiple sets of scanners 108 so that multiple static sEMG tests may be performed on multiple patients while the data from each static sEMG test are input to the hub 104 (and, optionally, to one or more processors 202), processed, and the results output to one or more displays, such as the visual display 204. The results of multiple static sEMG tests may be displayed concurrently on a single visual display 204. For example, the visual display 204 may include a split screen with static sEMG test results for two or more patients.

**[0052]** The measuring electrodes 1302 may be formed from many different conductive materials suitable for placement against the skin of a patient including, for example, gold, stainless steel, silver, silver chloride, and the like or combinations thereof. The ground 1308 may also be formed from many different conductive materials suitable for placement against the skin of a patient including, for example, gold, stainless steel, silver, silver chloride, and the like or combinations thereof. The ground 1308 is formed from the same conductive material as the measuring electrodes 1302.

**[0053]** The grounds 1308 of the scanners 108 are retractable in order to promote an improved contact between each ground 1308 and a patient when the scanners 108 are placed against the patient, and to also promote improved contact between the sets of measuring electrodes 1304 and 1306 and the patient, especially when the sets of measuring electrodes 1304 and 1306 are contacting curved portions of the patient, such as a patient's back.

**[0054]** Figure 14A is a schematic perspective view of one embodiment of one of the scanners 108 with the ground 1308 in an extended position and a portion of an outer casing of the scanner 108 removed, for clarity of illustration. A spring, such as spring 1402, is positioned

within the scanner 108 and used to provide the retractability of the ground 1308. It will be understood that any suitable type of spring may be implemented in the scanners 108 to provide retractability of the ground 1308

5 (e.g., tension, compression, torsional, coiled, flat, leaf, cantilever, hairspring, V-spring, or the like or combinations thereof). By allowing the ground 1308 to retract, the scanner 108 may be better able to adjust to contours of the body, and allow the first and second sets 1304 and 10 1306, respectively, of the measuring electrodes 1302 to contact the skin of a patient, even when there is a curve in the patient's body which, without retractability would cause the ground 1308 to lift at least one of the sets 1304 and 1306, respectively, of the measuring electrodes 1302 15 off the skin of the patient. Figure 14B is a schematic perspective view of one embodiment of one of the scanners 108 with the ground 1308 in a retracted position and a portion of an outer casing of the scanner 108 removed, for clarity of illustration.

20 **[0055]** Action potentials measured by the scanners 108 may be no greater than one milli-volt. Accordingly, ground loop protection and noise reduction may be important concerns. Noise is reduced, in part, by using wire links for each measuring electrode that are of similar length.

25 **[0056]** One or more of the measuring electrodes 1302 are pivotable to adapt to changes in body contours of a patient when, for example, the scanner 108 is pressed against the patient's body. Figure 15 is a schematic side view of one embodiment of the measuring electrodes 1302 of one of the scanners 108 with the measuring electrodes 1304 and 1306 each pivoted at different angles from one another. One or more of the measuring electrodes 1302 utilize an independent suspension system.

30 One or more of the measuring electrodes 1302 utilize a ball- and-socket system.

**[0057]** Figure 16 is a schematic view of a user 1602 using the scanners 108 to perform a static sEMG test on a patient 1604. Each of the scanners 108 is positioned 40 in lateral proximity to a spine of the patient 1604 at various levels of the spine. For example, in Figure 16 the scanners 108 are positioned in lateral proximity to a cervical portion of the patient's spine. As discussed above, the scanners 108 each include two sets of measuring electrodes 1302. Thus, in Figure 16 measurements can be taken concurrently at two spinal levels during each placement of the scanners 108 against the patient.

**[0058]** Over time, a series of measurements are obtained at different levels of the patient's spine. Action 45 potentials of muscles are measured and the corresponding data is transferred to the hub 104 (and, optionally, one or more processors 202 via the hub 102), the data is processed, and results are displayed on one or more displays, such as the one or more visual displays 204.

**[0059]** The scanners 108 are powered by one or more batteries. During a static sEMG test the corresponding software executes a command to power off the scanners 108 for a period of time between successive placements

to save battery power. During a static sEMG test the corresponding software executes a command to power on the scanners 108 when the scanners 108 are positioned against a patient, or when the controller 1310 is engaged. During a static sEMG test the corresponding software executes a command to power off the scanners 108 after the one or more controllers 1310 are engaged.

**[0060]** The hub 104 or the one or more processors 202 provide a prompt to alert the user 1602 when the scanners 108 are properly positioned against the patient 1604. In some embodiments, one or more of the positioning information and instructions for progressing through a static sEMG test is displayed on the one or more visual displays 204. In other embodiments, the positioning information is provided via one or more voice commands.

**[0061]** Figure 17 is a schematic view of two exemplary results 1702 and 1704 for a static sEMG test performed on a patient. In other embodiments, the two results 1702 and 1704 are from a single patient. In at least some embodiments, the two results 1702 and 1704 are from two different patients. In at least some embodiments, one of the two results 1702 and 1704 is from a patient and the other result is a model result, such as an "ideal" result to compare against the patient's result.

**[0062]** As discussed above, the scanners 108 may include various numbers of sets of measuring electrodes. More than two sets of measuring electrodes may be used. Additional grounds may also be used. The measuring electrodes are coupled to hand-held scanners, such as the scanners 108. Measuring electrodes may be coupled to scanners that may be self-standing or mounted to one or more planar surfaces, such as a wall.

**[0063]** Figure 18 is a schematic perspective view of a static sEMG scanner 1802 with twenty-four sets of measuring electrodes 1803. The static sEMG scanner 1802 includes a base 1804, two columns 1806 and 1808 of sets of measuring electrodes 1803 mounted to one or more mounting boards 1810, and at least one ground 1812. Each column 1806 and 1808 includes a plurality of sets of measuring electrodes 1803, such as set 1814. In at least some embodiments, the static sEMG scanner 1802 is coupled to the hub 104.

**[0064]** The measuring electrodes 1803 are retractable. Thus, when a patient contacts the measuring electrodes 1803, the measuring electrodes 1803 retract some amount of distance. When the static sEMG scanner 1802 is mounted to a wall, the static sEMG scanner 1802 is positioned away from the wall far enough to accommodate the retraction of the measuring electrodes 1803 as the patient contacts the measuring electrodes 1803. The static sEMG scanner 1802 includes one or more spacer bars 1816 to prevent one or more of the measuring electrodes 1803 from contacting a wall on which the static sEMG scanner 1802 is mounted when a patient is contacting (and consequently retracting) one or more of the measuring electrodes 1803. The measuring electrodes 1803 may be adjusted for improved contact against pa-

tient skin during a static sEMG test. The two columns 1806 and 1808 of measuring electrodes 1803 are moveably mounted such that they can be moved horizontally closer together or further apart from one another to improve measuring electrode 1803 contact with patients with spines of various widths. The height from the floor of each of the columns 1806 and 1808 may be raised or lowered to improve measuring electrode 1803 contact with patients of different heights.

**[0065]** A pivot extends between measuring electrodes 1803 of each set of measuring electrodes 1803 to improve contact with patients. In Figure 18, the pivots are shown as two bars 1818 and 1820 extending vertically between measuring electrodes of each set of measuring electrodes 1803. The measuring electrodes 1803 are mounted on a pliable substance, such as rubber, which facilitates a left/right pivot for each set of measuring electrodes 1803.

**[0066]** Accompanying software distinguishes measuring electrodes 1803 making contact with patient skin from measuring electrodes 1803 not making patient-skin contact. The software can detect when action potential measurements from one or more of the measuring electrodes 1803 are zero (no patient contact). A user can select the top and bottom measuring electrodes 1803 of the two columns 1806 and 1808 making contact with a patient from a display showing the measuring electrodes 1803. For example, the user can select that the top two sets of measuring electrodes 1803 of each of the mounting boards 1810 are to be ignored (e.g., when performing a static sEMG test on a particularly short patient). As another example, the user may select the top measuring electrode sets to be at the Cervical level 4 ("C4") of a patient and the bottom measuring electrode sets to be at Lumbar level 1 ("L1") of the patient, with the bottom six sets of measuring electrodes not contacting the patient.

**[0067]** Figure 19 is a schematic side view of one of the measuring electrodes 1803 of the static sEMG scanner 1802. The measuring electrode 1803 includes a curved contact surface 1904 mounted to a conductive member 1906 which, in turn is mounted to the mounting board 1810. The conductive member 1906 is coupled to a spring 1908. The spring 1908 facilitates the retraction of the measuring electrode 1803 when a patient contacts the contact surface 1904 of the measuring electrode 1803. In one specific example, the spring 1908 is configured and arranged so that the measuring electrode 1803 may be retracted up to twelve inches (approximately 30 cm).

**[0068]** Figure 20 is a schematic view of four measuring electrodes 1803 in a first position 2004 and a second position 2006 that is horizontally pivoted from the first position 2004. Pivotable measuring electrodes may improve contact between the measuring electrodes 1803 and a patient when the patient is contacting the measuring electrodes 1803. The measuring electrodes 1803 are pivoted about a pivot, such as one of the bars 1818 and

1820. Alternatively, the measuring electrodes 1803 may pivot horizontally. In other embodiments, the measuring electrodes 1803 may pivot vertically. In other examples, the measuring electrodes 1803 may pivot along other axes other than a horizontal or a vertical axis. In other examples, patient contact is improved by using a pliable material, such as rubber, to form the non-contact surface of the measuring electrodes, the pliable material facilitating the bending of the measuring electrodes as needed when a patient is contacting the contact surface 1904 so as to improve contact. 5

[0069] Figure 21 is a schematic rear view of the static sEMG scanner 1802 aligned against a back of a human figure 2102. In Figure 21 the two columns 1806 and 8108 of the measuring electrodes 1803 and the ground 1812 are contacting the back of the human figure 2102. The two columns 1806 and 1808 of the measuring electrodes 803 are configured and arranged so that the measuring electrodes 1803 are contacting the back of the human figure 2102 in lateral proximity to the spine of the human figure 2102. 10 15

[0070] Further insight into the nature and extent of patient injury may be obtained by further including one or more video cameras, such as video camera 206, to capture one or more images or videos of the performance of the static sEMG test. Figure 22 is a schematic top view of an exemplary testing arrangement for generating images of the patient undergoing a static sEMG test. In Figure 22, three video cameras: 2202, 2204, and 2206, are positioned around a mat 2208 that includes regions 2210 and 2212, representing a location for a patient to stand on during performance of the static sEMG test. The video camera 2202 is positioned directly in front of a patient standing on the regions 2210 and 2212, while the video camera 2204 is positioned directly behind the patient, and while the video camera 2206 is positioned to one side of the patient. At least one of one or more videos or one or more still images may be generated of the patient while the patient undergoes a static sEMG test. 20 25 30 35

[0071] The addition of video (or one or more captured images) from one or more different angles may be made available for review by one or more medical practitioners. The data from the static sEMG test and the one or more captured video (or static images) may be stored on the one or more processors 202 so that one or more medical practitioners may see precisely the positioning of the patient when the data was collected for a static sEMG test. Moreover, a similar test may be subsequently performed on the same patient in order to track patient progress over time. 40 45 50

[0072] The above specification, examples and data provides a description of the manufacture and use of the composition of the invention. Many embodiments of the invention can be made without departing from the scope of the invention, as set out in the claims hereinafter appended. 55

Krav

1. Skanner (108) til elektromyografi af statisk overflade ("sEMG") konfigureret til at måle aktivitetspotentialer langs udvalgte muskelgrupper i en patient, den statiske sEMG skanner omfatter:

mindst to sæt måleelektroder (1302), som strækker sig fra den statiske sEMG skanner (108), de mindst to sæt måleelektroder (1302) er konfigureret og arrangeret til at blive placeret mod en patients hud i lateral nærhed af patientens ryg; og  
mindst en jordforbindelse (1308) konfigureret og arrangeret til at blive placeret mod patienthud væk fra de mindst to sæt måleelektroder (1302),  
**kendetegnet** ved at  
den mindst ene jordforbindelse (1308) er tilbagetrækkelig for at fremme en forbedret kontakt mellem hver af den mindst ene jordforbindelse (1308) og patienten, når de mindst to sæt måleelektroder (1302) placeres mod patienten;  
og ved at den statiske sEMG skanner (108) er konfigureret og arrangeret til at være håndholdt af en bruger under målingen af aktivitetspotentialer langs patientens udvalgte muskelgrupper, mens patienten bevarer en særlig position.
2. Statisk sEMG skanner (108) ifølge krav 1, hvori de mindst to sæt måleelektroder (1302) hver er i stand til at dreje.
3. System (100) til at diagnosticere skade i blødt væv og konfigureret til at diagnosticere skade i blødt væv inden i en patient, systemet (100) til at diagnosticere skade i blødt væv omfatter:

skanneren (108) til elektromyografi af statisk overflade ("sEMG") ifølge krav 1;  
et sæt håndholdte inklinometre (102) omfattende en hovedenhed (402) og en hjælpeenhed (404), inklinometrene (102) er konfigurerede og arrangerede til at blive placeret tæt på to ender af patients kropsdel, som bevæger sig om et patientled ved én ende af kropsdelen, således at hovedenheden (402) er placeret tæt på leddet, og hjælpeenheden (404) er placeret langs den kropsdel på patienten, som bevæger sig omkring et patientled, inklinometrene er konfigurerede og arrangerede til at måle vinkler dannet mellem hovedenheden (402) og hjælpeenheden (404) under patientens kontrollerede bevægelser af leddet;

et dynamisk overfladeelektromyograf ("sEMG") modul (106) og mindst et sæt måleelektroder (806), som er elektrisk koblede til det dynamiske sEMG modul (106), måleelektroderne (806) er konfigurerede og arrangerede til at koble til en ydre del af patienten i lateral nærhed af et stort antal niveauer af patientens ryg langs den kropsdel, som bevæger sig omkring leddet, det mindst ene sæt måleelektroder (806), som er konfigurerede og arrangerede til at måle aktivitetspotentialer langs en patients muskelgrupper under måleelektroderne under patientiens kontrollerede bevægelser af leddet og til at transmittere de målte aktivitetspotentialer til det dynamiske sEMG modul (106);

en hub (104), som er konfigureret og arrangeret til at modtage de data, som er opsamlet fra inklinometrene (102) og det dynamiske sEMG modul (106) under patientens kontrollerede bevægelser af leddet, og til at bearbejde de modtagne data til mindst et billede, der kan vises; og

en visuel skærm (204) elektrisk koblet til hubben (104), den visuelle skærm (204) er konfigureret og arrangeret til at modtage og til at vise hubbens (108) bearbejdede data.

4. Statisk sEMG skanner (108) ifølge krav 1, hvori de mindst to sæt måleelektroder (1302) er placeret på den statiske sEMG skanners (108) frontende.
5. Statisk sEMG skanner (108) ifølge krav 1, hvori den mindst ene jordforbindelse (1308) er placeret på den statiske sEMG skanners (108) frontende.
6. Statisk sEMG skanner (108) ifølge krav 1, yderligere omfattende en eller flere styreenheder (1310), som er konfigurerede til, uden at anvende et numerisk tastatur, tastatur eller lignende, at styre forløbet under målingen af aktivitetspotentialer langs patientens udvalgte muskelgrupper mellem på hinanden følgende placeringer af måleelektroderne (1302) mod patienthud, mens patienten fastholder en særlig position.
7. Statisk sEMG skanner (108) ifølge krav 1, yderligere omfattende en eller flere indikatorer (1312) konfigurerede til at tilvejebringe indikationer til en bruger før, under eller efter måling af aktivitetspotentialer langs en patients udvalgte muskelgrupper, mens patienten fastholder en særlig position.

8. Statisk sEMG skanner (108) ifølge krav 1, hvori de mindst to sæt måleelektroder (1302) hver omfatter to elektroder.
9. Statisk sEMG skanner (108) ifølge krav 1, hvori den mindst ene jordforbindelse (1308) er placeret mellem de mindst to sæt måleelektroder (1302).
10. Statisk sEMG skanner (108) ifølge krav 1, hvori måleelektroderne i de mindst to sæt måleelektroder (1302) er placeret med en horizontal afstand fra hinanden langs den statiske sEMG skanners (108) frontende, og den mindst ene jordforbindelse (1308) er placeret vertikalt mellem de mindst to sæt måleelektroder (1302).
11. Statisk sEMG skanner (108) ifølge krav 1, hvori måleelektroderne i de mindst to sæt måleelektroder (1302) er placeret med en vertikal afstand fra hinanden langs den statiske sEMG skanners (108) frontende, og den mindst ene jordforbindelse (1308) er placeret horizontalt mellem de mindst to sæt måleelektroder (1302).
12. Statisk sEMG skanner (108) ifølge krav 1, hvori den statiske sEMG skanner (108) er trådløs.
13. Statisk sEMG skanner (108) ifølge krav 1, hvori en fjeder (1402) er placeret inden i den statiske sEMG skanner (108) og anvendt til at tilvejebringe at jordforbindelsen kan trækkes tilbage.
14. Statisk sEMG skanner (108) ifølge krav 1, hvori mindst en måleelektrode af de mindst to sæt måleelektroder (1302) anvender et uafhængigt ophængningssystem.
15. Statisk sEMG skanner (108) ifølge krav 1, hvori mindst en måleelektrode af de mindst to sæt måleelektroder (1302) anvender et kugleledssystem.

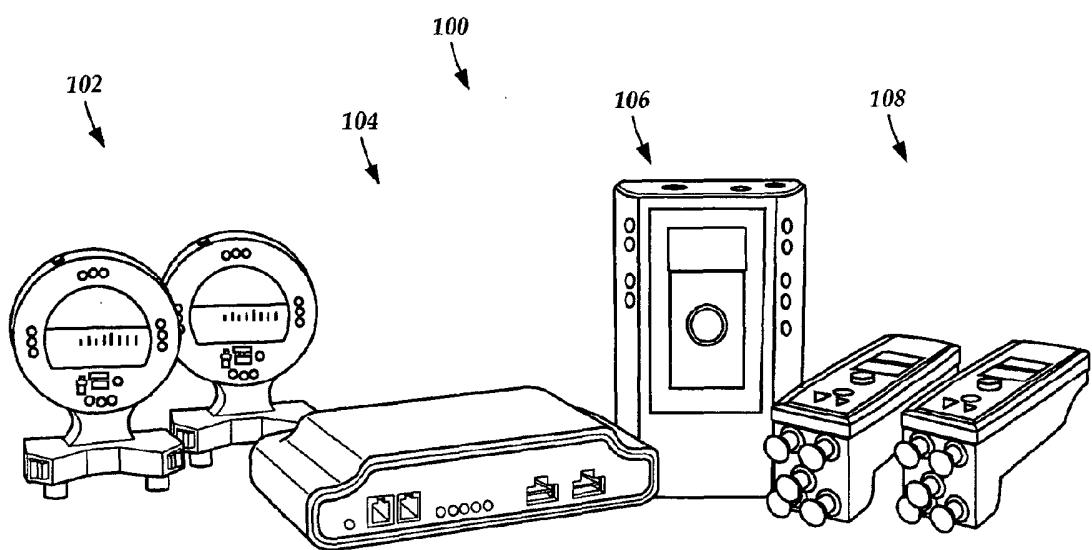
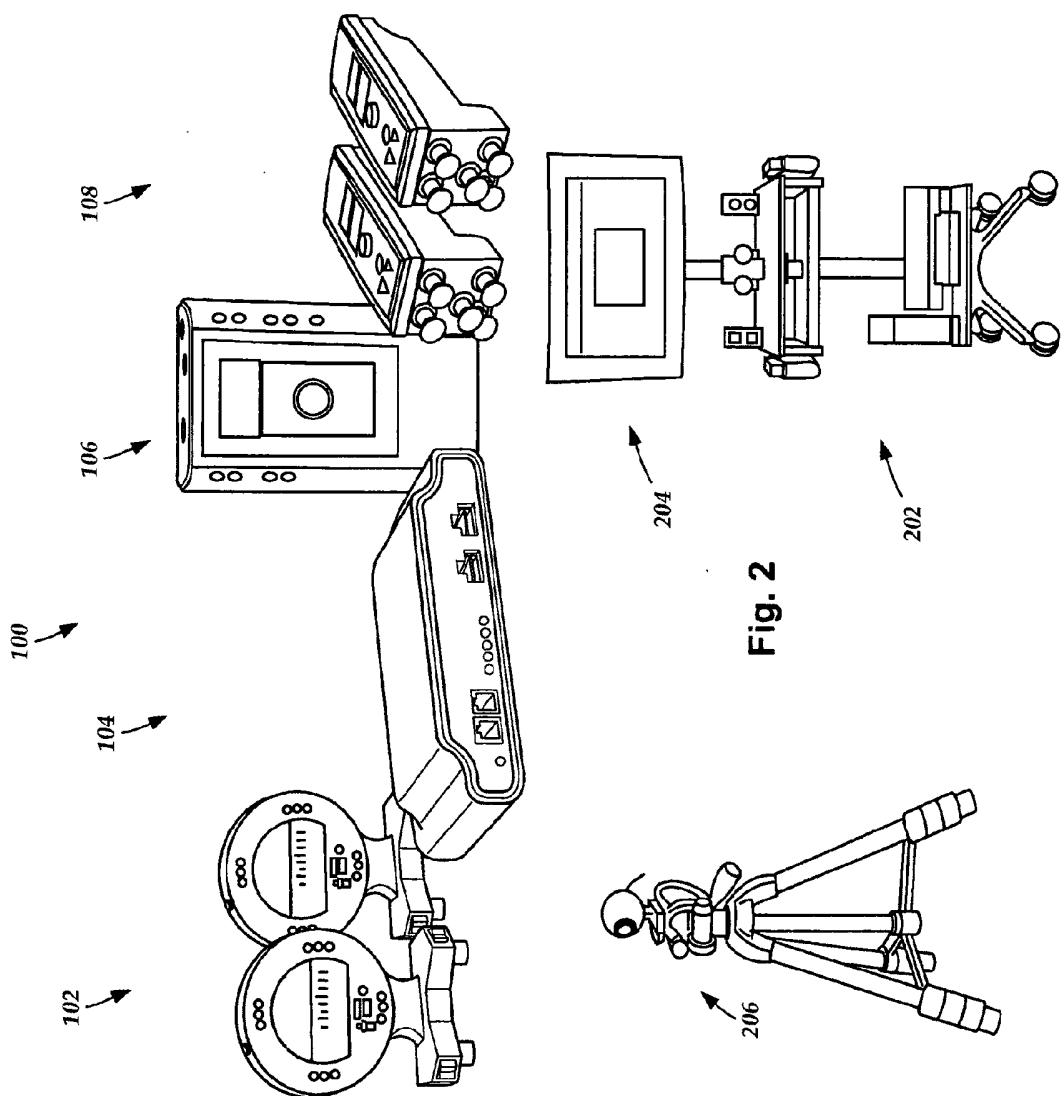


Fig. 1



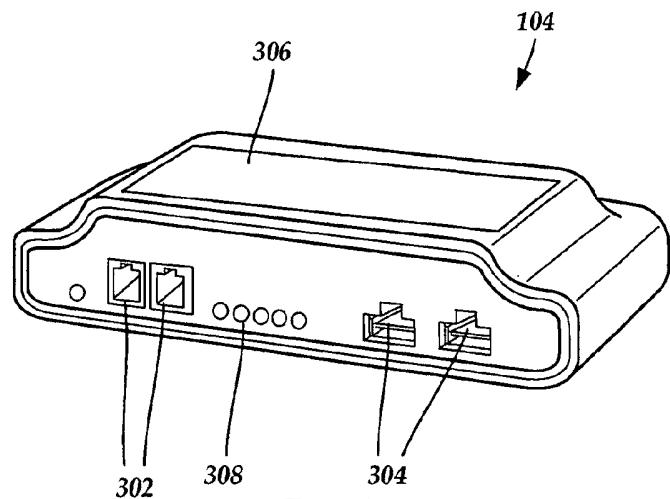


Fig. 3

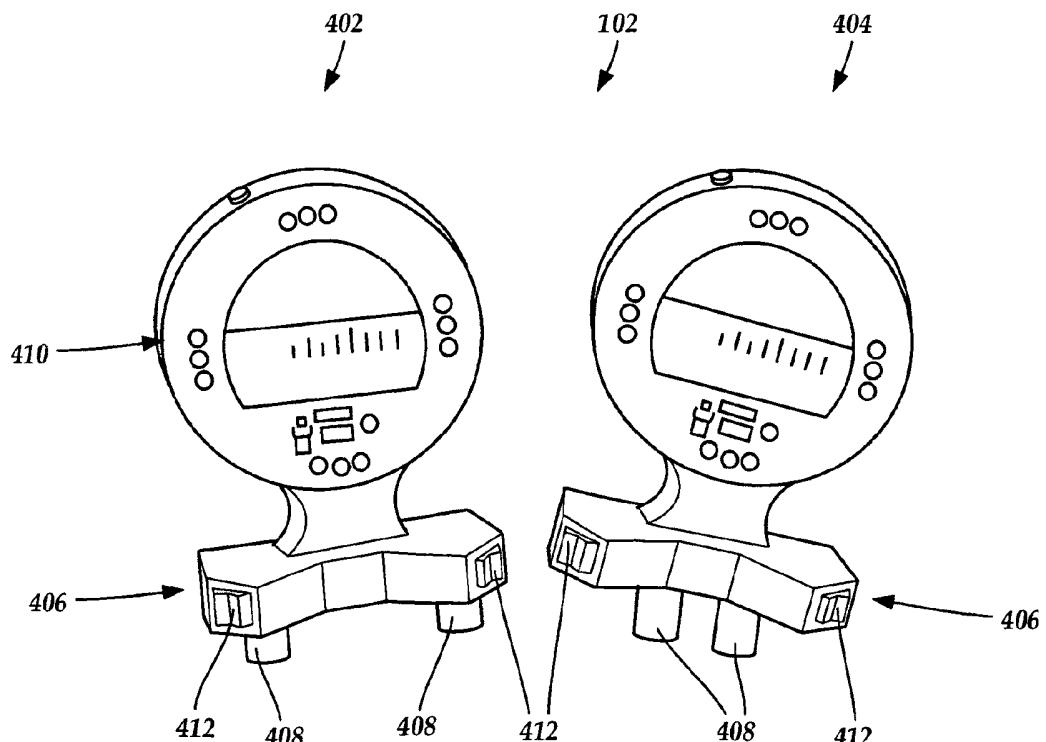
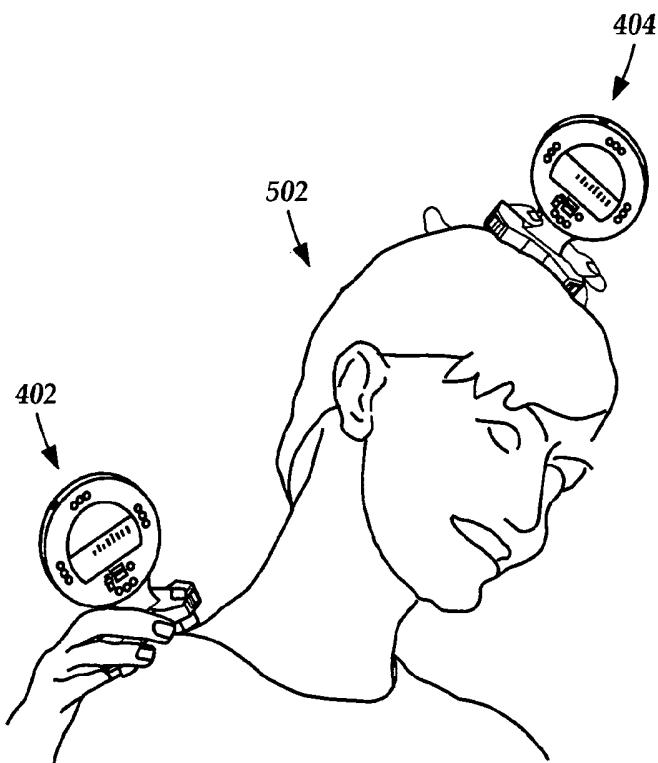
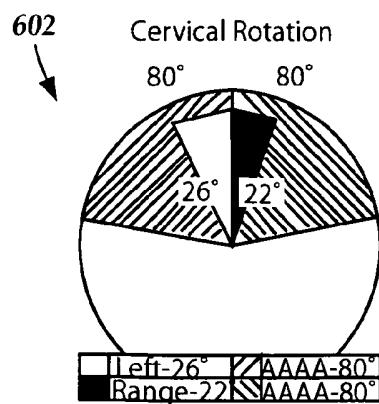


Fig. 4



**Fig. 5**



**Fig. 6**

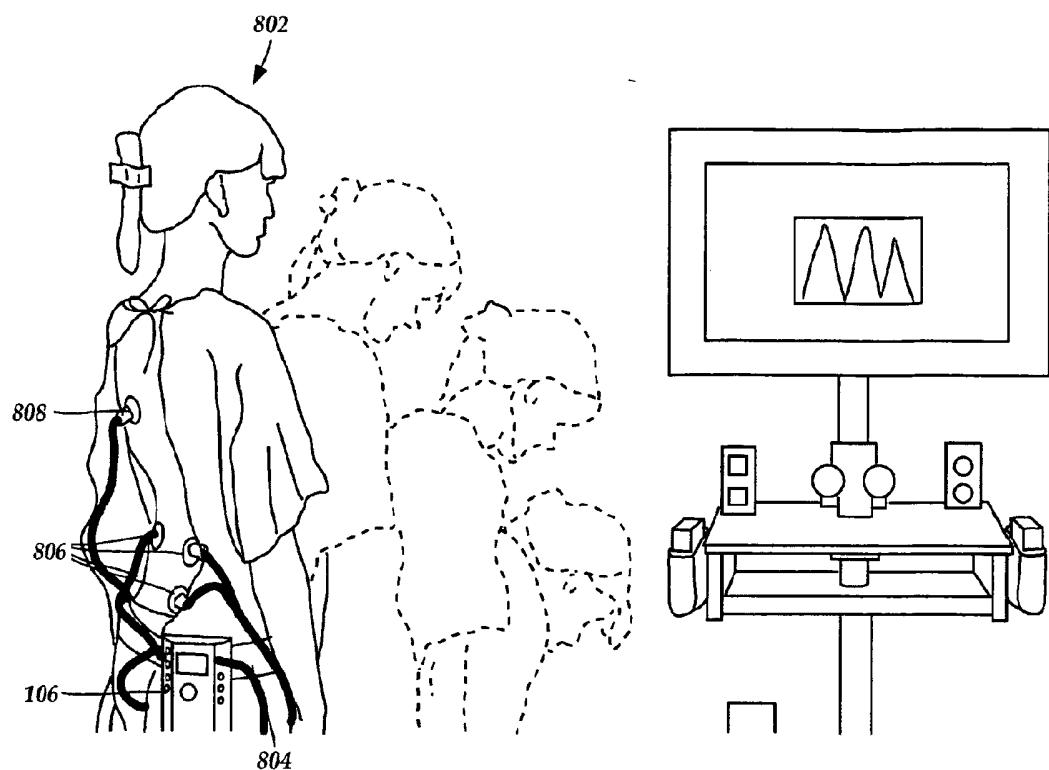


Fig. 8

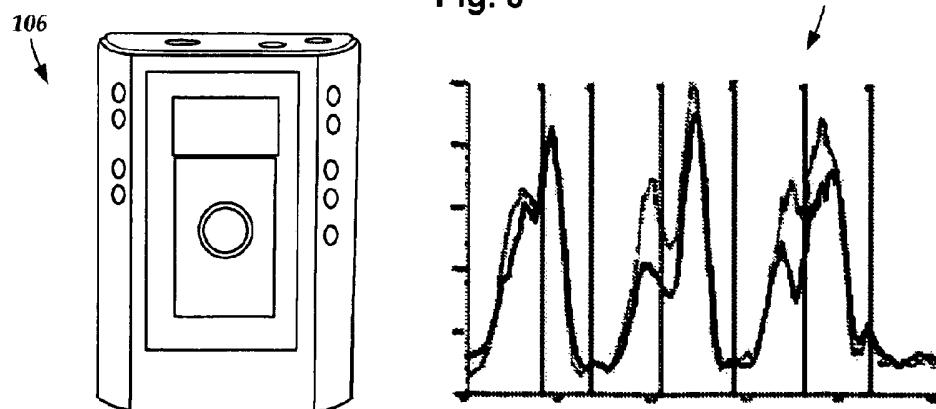


Fig. 7

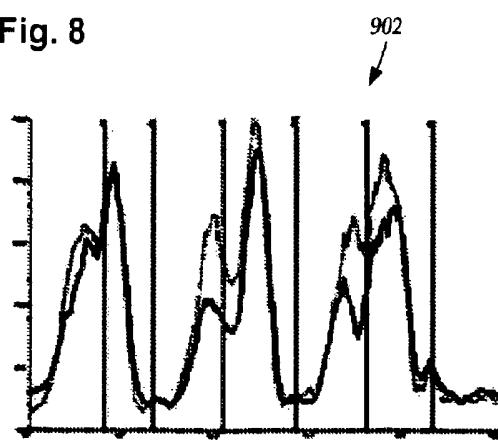


Fig. 9

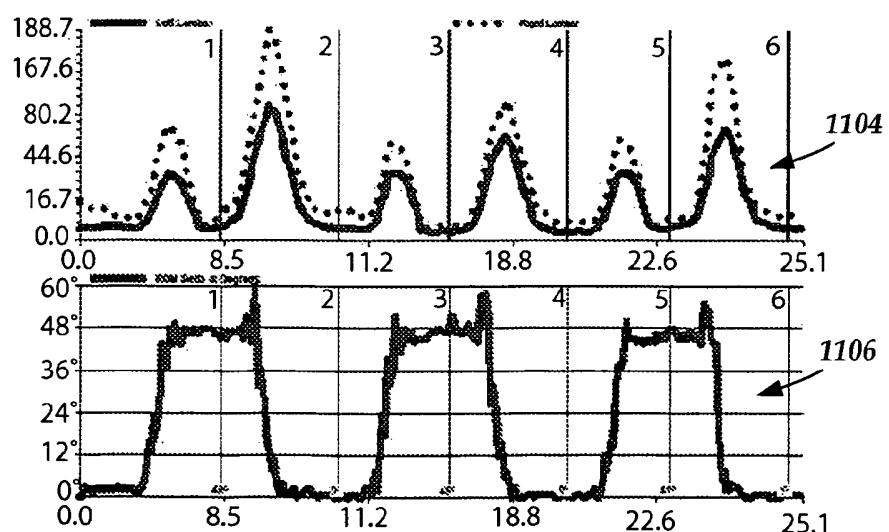
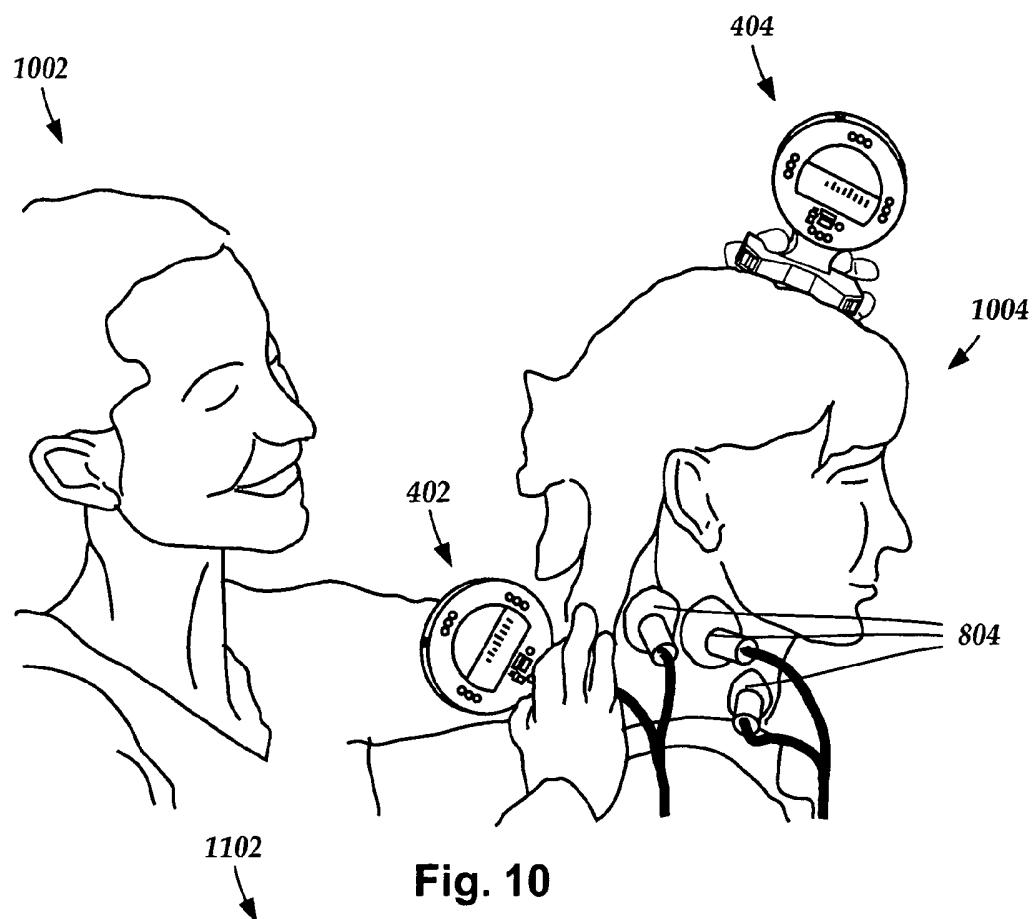


Fig. 11

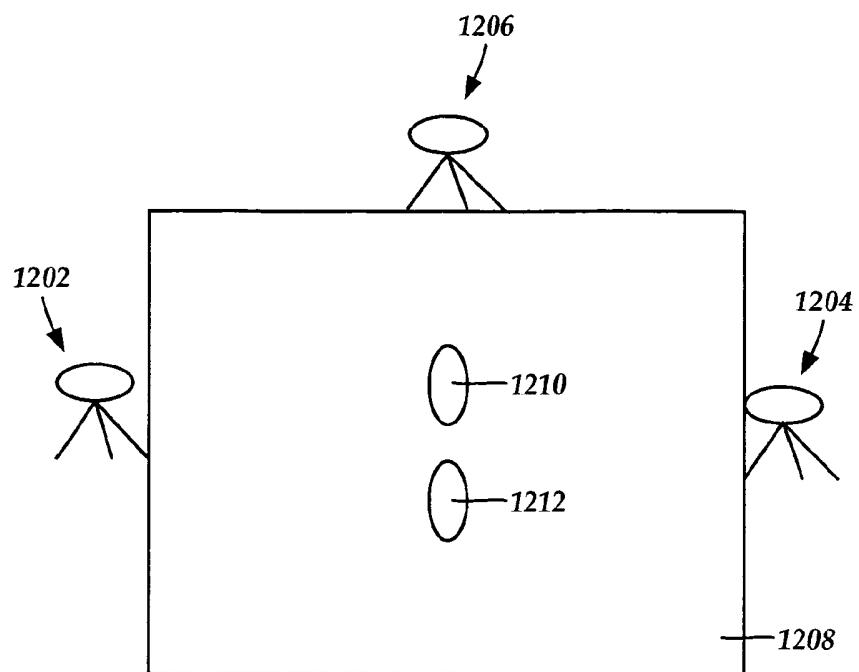


Fig. 12

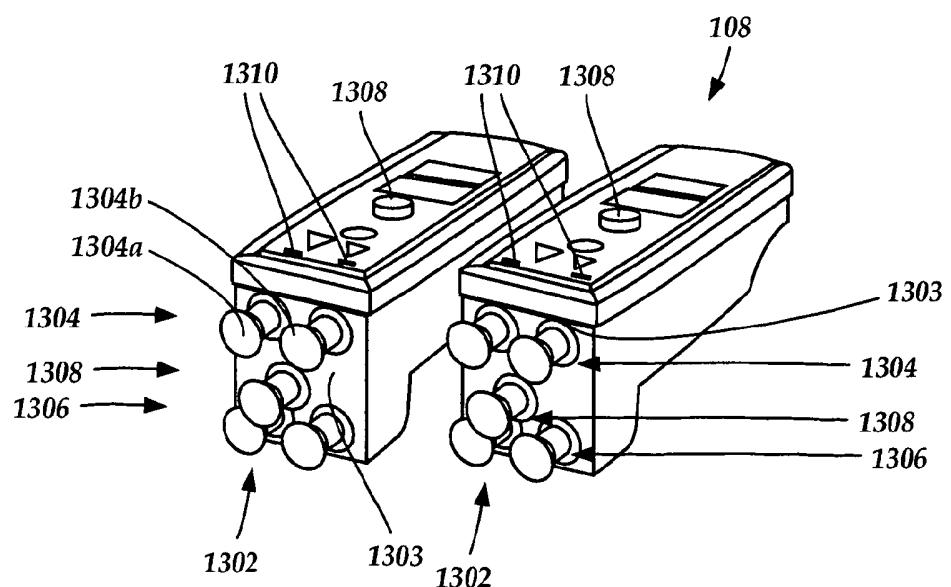
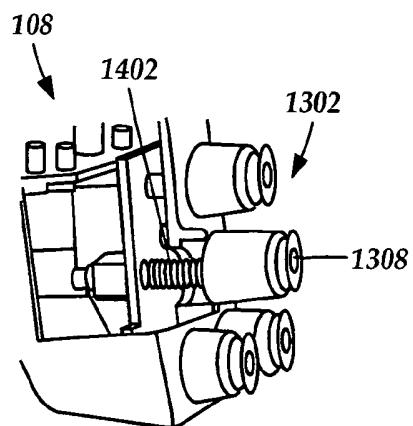
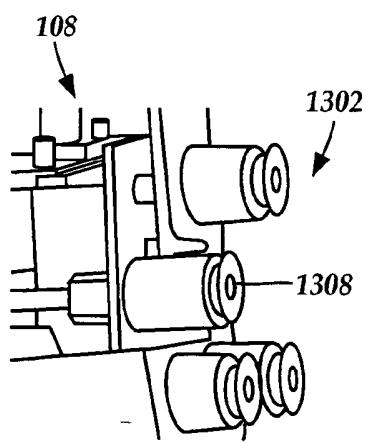


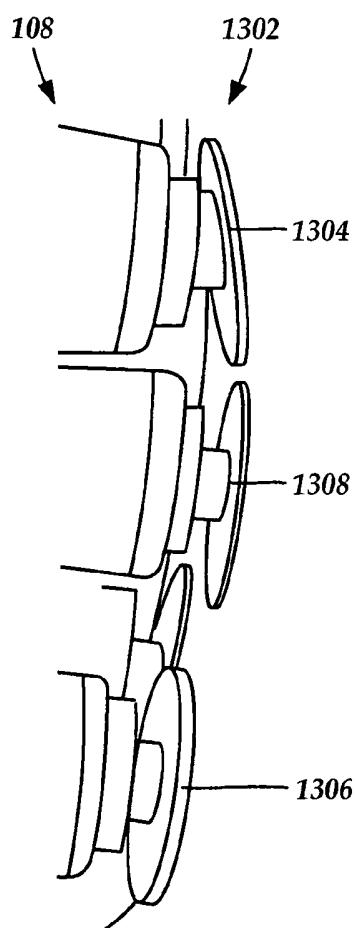
Fig. 13



**Fig. 14A**



**Fig. 14B**



**Fig. 15**

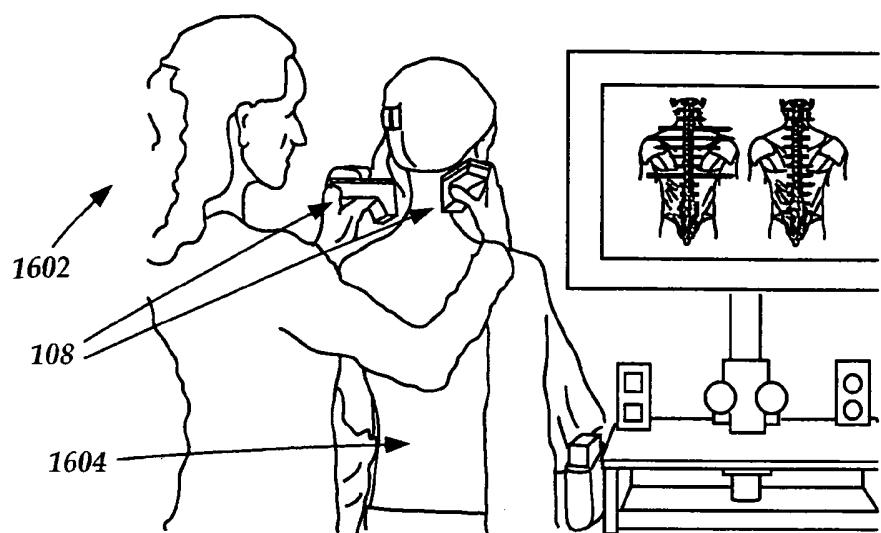


Fig. 16

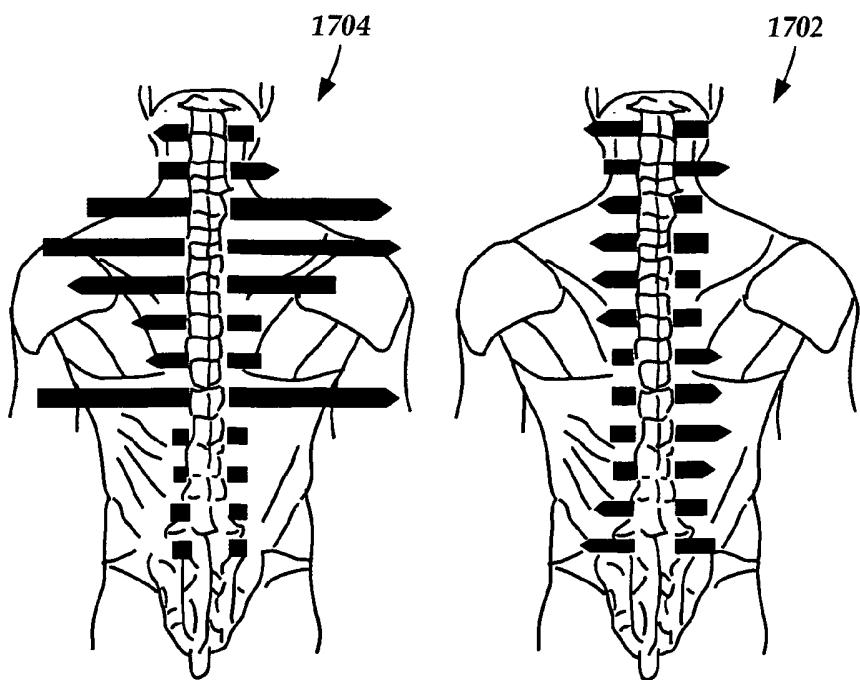


Fig. 17

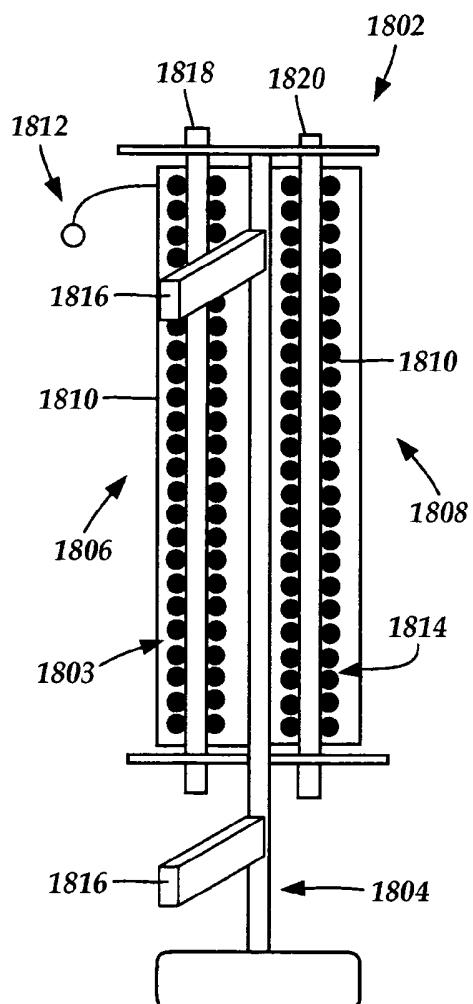


Fig. 18

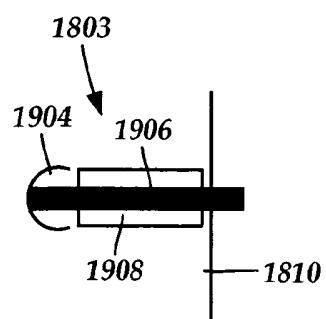


Fig. 19

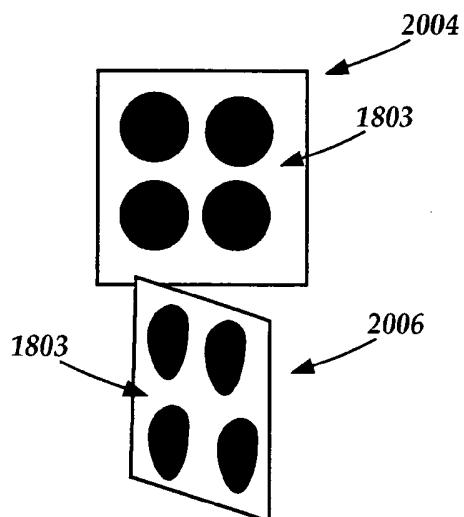


Fig. 20

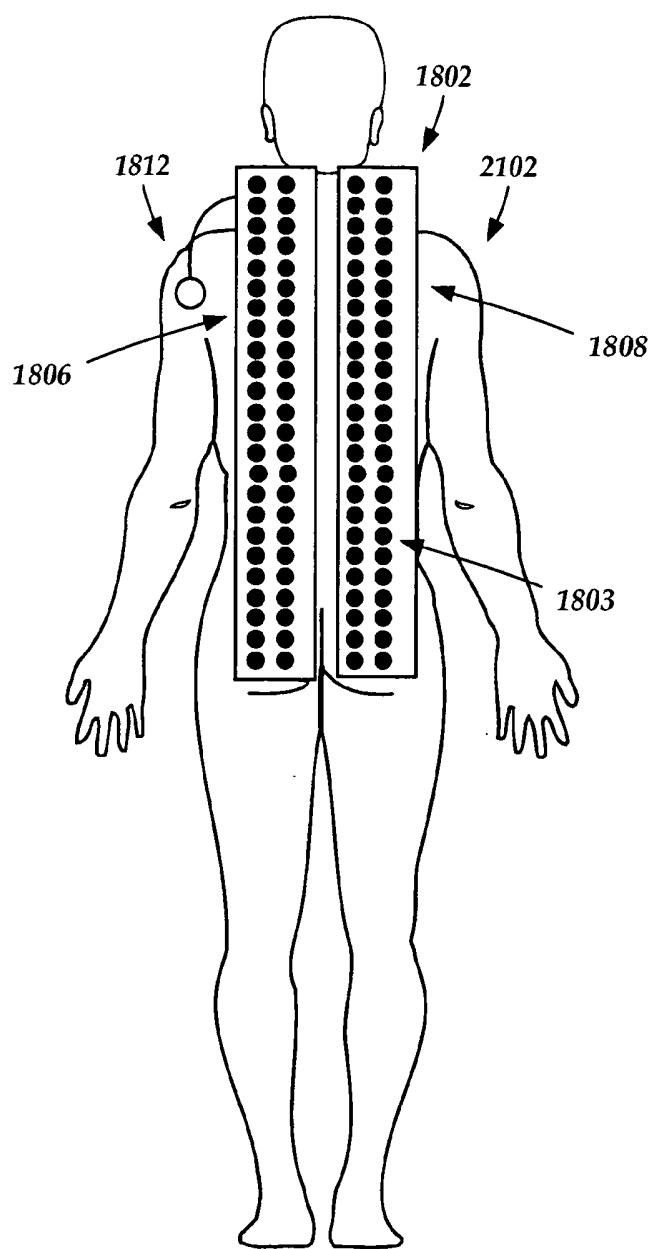
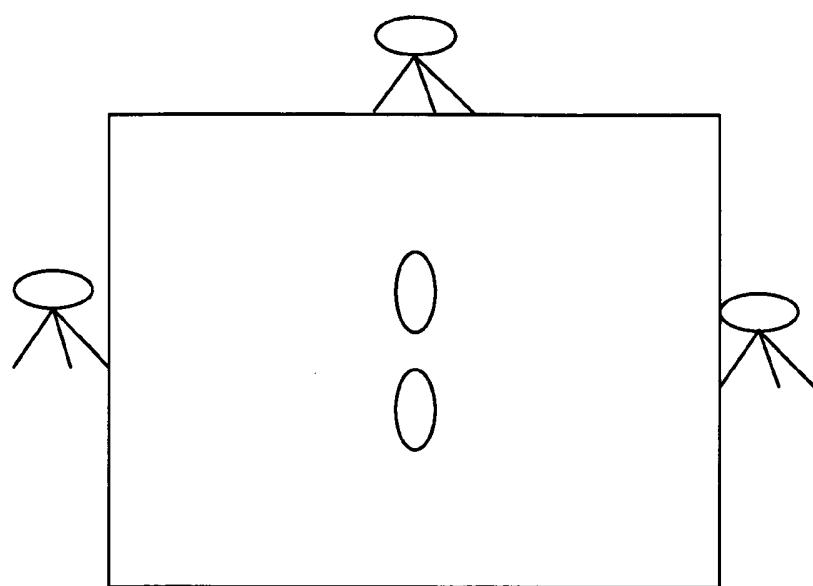


Fig. 21



**Fig. 22**