

METHOD AND APPARATUS FOR POST-SPINAL SURGERY AND/OR POSTURE MONITORING

Brief Background

The spine is a very critical component of the human body. The spine is the main distribution line for nerve signals from the brain to the rest of the body. Although, the spinal cord is protected by segmented bones (vertebra), it is not immune to injury and disease. Medical procedures such as discectomies and laminectomies where certain parts of the lamina and the spinal discs are removed due to deformity leaves a portion of the spinal column weak. It has always been advised by medical professionals to ensure that no re-injury happen months after any of the mentioned procedures. The invention claimed in this document provides the necessary monitoring needed to ensure that patients needing post-operative care have the independent method of ensuring that their spines are kept within safe dynamics. Current methods of post-operative care mainly use mechanical apparatuses (corsets) that do not interactively provide feedback to the user.

In addition, this device can be used by any person to monitor and provide spine health. Most of the working adults are desk-bound and are prone to diseases such as chronic back pain, sciatica, scoliosis etc. This device generates warnings that is useful for a person exposed to such working environments.

Technical Description

The invention is an independent apparatus, portable and programmable using embedded electronics technology and solid-state gyroscope and accelerometer sensors. The purpose of the invention is mainly to provide warning and alerts to the user of the device for prolonged lumbar and thoracic exposure to angles that may pose risk of further injury for post-operative care and to provide warning and alerts for a person of any bad posture after a programmed set of time. The system involved uses 2 sensors mounted on a garment worn by the user and adjustable through removable *Velcro* straps (refer to Figure 4). The device is not dependent on external devices such as smart phones or applications to function.

The alerts and warnings provided by the system are through audible synthesized speech, thus avoiding the dependency on visual alerts that could easily be overlooked by the user. In addition, a button on the device allows the user to determine at anytime, the Cobb Angle at a specific posture, so as to make sure that a certain position is within normal Cobb Angle limits. The Cobb Angle is the

parameter used by radiologists to determine the kyphotic abnormalities of the spine. By measuring the intersecting angles from lines perpendicular to the thoracic section and lumbar section, the Cobb Angle is measured. The angle is determined through following equation (refer to eq. 1):

$$\theta = \alpha + \beta \dots \text{eq. 1}$$

where:

θ = Cobb Angle (degrees)

α = Thoracic Angle (degrees) - measured from the vertical

β = Lumbar Angle (degrees) - measured from the vertical

The *Thoracic Angle* and *Lumbar Angle* are determined by the trigonometric calculations of the gravitational forces acting on the accelerometer sensors.

The following speech alerts are provided by the apparatus:

1. *"Thoracic Angle Critical!"*
2. *"Lumbar Angle Critical!"*
3. *"Sudden Bending Warning!"*
4. *"Sudden Twist Warning!"*
5. *"Facing Down Warning!"*
6. *"Lie Down Mode."*
7. *"Bad Posture Warning!"*
8. *"The Approximate Cobb Angle is NN degrees."*
9. *"Cobb Angle Error"*
10. *"Lumbar Sensor Temperature High"*
11. *"Thoracic Sensor Temperature High"*

The *"Thoracic Angle Critical!"* warning is generated by the device after the thoracic accelerometer sensor exceeds programmable parameters, *Thoracic Angle Limit* and *Thoracic Limit Delay*. This feature prevents the user from staying in a prolonged position where the thoracic section is angled where it can pose risk of injury or pain.

The *"Lumbar Angle Critical!"* warning is generated after the lumbar accelerometer sensor exceeds programmable parameters, *Lumbar Angle Limit* and *Lumbar Limit Delay*. This feature prevents the user from staying in a prolonged position where the lumbar section is angled where it can pose risk of injury or pain.

The "*Sudden Bending Warning!*" is generated through the thoracic gyro sensor after the angular velocity (across the sagittal anatomical plane) exceeds a programmable parameter, *Bending Limit*. This function warns the user to avoid any activity detected that causes sudden bends which can injure the spine.

The "*Sudden Twist Warning!*" is generated through the thoracic gyro sensor after the angular velocity (across the axial anatomical plane) exceeds a programmable parameter, *Twist Limit*. This function warns the user to avoid any activity detected that causes sudden bends which can injure the spine.

The "*Facing Down Warning!*" is generated if the sensor is at near horizontal position where the user seems to be facing down. This warning is used to indicate to the user that the spine is at risk of prolonged flexion across the sagittal plane.

The "*Lie Down Mode*" speech alert is generated to indicate that the user is presumably on a lying position, the device will be on standby mode.

The "*Bad Posture Warning!*" is generated when the Cobb Angle derived from the measurements of both thoracic and lumbar accelerometer sensors lie outside the safe limits which are also programmable parameters. The default value of the safe Cobb Angle is 20 - 40 degrees.

"*The Approximate Cobb Angle is NN degrees*" is generated after the user presses the Cobb Angle button. Through speech synthesis, the device generates the full numeric output of the Cobb Angle (hereto denoted as NN). This feature can be used for preliminary diagnosis of kyphosis or through the user's preference monitor his/her Cobb Angle at anytime.

The "*Cobb Angle Error!*" is generated when the Cobb Angle lies outside measurable parameters (when the perpendicular lines across the thoracic and lumbar sections are parallel and further diverge outwards).

The "*Lumbar Sensor Temperature High!*" warning provides an audible alert if the sensor is exposed to an environment exceeding a programmable value, *Lumbar Temp Limit*. This provides a warning to the user if his/her spine is within a specific operating temperature.

The "*Thoracic Sensor Temperature High!*" warning provides an audible alert if the sensor is exposed to an environment exceeding a programmable value, *Thoracic Temp Limit*. This provides a warning to the user if his/her spine is within a specific operating temperature.

The device also allows volume control for the audible speech warnings, thus allowing the user to adjust comfortable preferences.

Review of Existing Filings

An existing domestic patent (no. 1996016704) indicated somehow similar claims to this invention however, the sensors indicated in the patent do not use solid-state gyro-accelerometers. Furthermore, other domestic IP protection regarding apparatus dealing with the spine are trademarks. These statements of course are still subject to the inquiry and examination.

Description of Figures

Figure 1. Shows the complete set-up of the apparatus. There are 4 main components, the 'processor unit', 'thoracic sensor', 'lumbar sensor' and the garment. The garment is basically a tight-fit air-cool shirt with a sewn *Velcro* strip that allows quick attachment and adjustment of the sensors. The processor unit is connected via a thin bus cable connecting both the sensors on a single set of wires back to the processor unit. The thoracic sensor is typically placed near the T2 section of the spine while the lumbar sensor is placed on the T12 section of the spine. The sensors can easily be disconnected from the sensor bus through attachment headers, while the main sensor bus can also be disconnected from the processor unit. The devices can be removed from the garment to enable laundry to be done without damage to the devices.

Figure 2. Shows the main processor unit. It is equipped with a microcontroller, external memory device (SD card), audio amplifier, speaker/transducer, Cobb Angle button, LED indicator lights and an arm band. It is portable and lightweight. The sensor bus wire is connected to the sensor bus port.

Figure 3. Shows the physical illustration of the thoracic and lumbar sensors. Each sensor has a solid-state gyroscope, accelerometer and temperature sensor in one module. This device is installed inside a plastic enclosure shaped as shown in the figure. The sensor has gyro-flaps which provides more sensitivity for twisting motions. The sensor has a *Velcro* strip that allows connection to the garment.

Figure 4. Shows the spine sensor garment with *Velcro* strip. This garment is tight-fit to allow a more accurate measurement of the spine angles, and air-cool so as to allow a user to wear another garment on top of it without much discomfort.

Figure 5. Shows how the Cobb Angle is measured by the 2 sensors. The measurement is done through an algorithm programmed in the microcontroller of the main processor unit.

The embodiments of the invention in which exclusive property or privilege is claimed are defined as follows:

1. A portable electronic monitoring apparatus with internal battery that is independent of any external support such as smart phones and applications to monitor spine dynamics and spinal column section angles through the use of solid-state gyro-accelerometer sensors.
2. A portable electronic apparatus which monitors spinal external physical characteristics through the use of solid-state gyro-accelerometer sensors such as:
 - a. angle of thoracic section
 - b. angle of lumbar section
 - c. Cobb Angle
 - d. twisting of the spine across the axial anatomical plane
 - e. bending of the spine across the sagittal anatomical plane
 - f. lumbar section temperature
 - g. thoracic section temperature
3. Such that as from number 2 above, synthesized speech is generated to provide warning to the user of the device. Audible alerts and warnings generated are:
 - a. "Thoracic Angle Critical!"
 - b. "Lumbar Angle Critical!"
 - c. "Sudden Bending Warning!"
 - d. "Sudden Twist Warning!"
 - e. "Facing Down Warning!"
 - f. "Lie Down Mode."
 - g. "Bad Posture Warning!"
 - h. "The Approximate Cobb Angle is NN degrees."
 - i. "Cobb Angle Error"
 - j. "Lumbar Sensor Temperature High"
 - k. "Thoracic Sensor Temperature High"

4. A portable electronic device using gyro-accelerometer sensors capable of measuring the kyphotic and Cobb Angles and provide audible value of the Cobb Angle measurement through the press of a button.
5. A portable electronic apparatus which monitors spinal external physical characteristics through the use of solid-state gyro-accelerometer sensors which is easily detachable by the wearer through quick-release attachments, straps and bands, disassembly does not require use of special tools.
6. A portable electronic apparatus which monitors spinal external physical characteristics through the use of solid-state gyro-accelerometer sensors which also monitors sensor temperature and provides audible alert to the user for high temperature warnings.
7. A portable electronic apparatus which monitors spinal external physical characteristics through the use of solid-state gyro-accelerometer sensors where limit parameters are programmable to suit patient and user requirements.
8. A portable electronic apparatus which monitors spinal external physical characteristics through the use of solid-state gyro-accelerometer sensors which includes a removable external memory storage device for synthesized speech files storage such that:
 - a. The synthesized voice or audio files can be replaced by other recorded synthesized or audio files.
 - b. Other synthesized voice or audio files can be added for additional warnings.
9. A portable electronic apparatus which monitors spinal external physical characteristics through the use of solid-state gyro-accelerometer sensors, where the sensors are housed in a rigid plastic that has horizontal elongated flaps that increases gyro sensing capabilities.
10. A portable electronic apparatus which monitors spinal external physical characteristics through the use of solid-state gyro-accelerometer sensors equipped with indicator LEDs for additional visual warnings such as:
 - a. red LED for spine angle and movement warnings

- b. yellow LED for synthesized speech memory storage error
 - c. green LED for "lie-down" sleep mode
11. A portable electronic apparatus which monitors spinal external physical characteristics through the use of solid-state gyro-accelerometer sensors which uses a single bus cable to connect multiple sensors such that:
- a. The sensors are easily detached by the user from the bus without special tool
 - b. The sensor bus disconnects from the main unit without the need for special tool
12. A portable electronic apparatus which monitors spinal external physical characteristics through the use of solid-state gyro-accelerometer sensors equipped with firmware-upgradeable microcontroller.