The Enhanced Posture Correction Calibration Devices Using Bio-Sensors on WSN

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Chronic pains and herniated disks are common diseases that about 80% of adults have experienced. Among the diseases, the rate of traffic accidents and accidental falls comprise only about 10%, whereas the vast number of such diseases are caused by patients habitual wrong posture in their daily lives. In general, people who suffer such back-related diseases often do not recognize that their habitual incorrect posture in their common activities are the main causes of their pains. In this paper, we present a system which collects the data from sensors placed on the user’s body, and suggests a correct posture for the patient after conducting a series of correct position prediction tests. We believe this system could be beneficial to children and chronic patients to correct their postures by repeating their cognitive trainings. In order to prove its effectiveness, we have built a wireless body area network (WBAN) test-bed and conducted a series of tests which considered both patient’s vital signs and situation-aware information.

Keywords: Human information processing, Human safety, Biology and genetics, Health, Medical information system

ACM Classifications: H.1.2 (User/Machine System): Human information processing; K.4.1 (Public Policy Issue): Human safety; J.3 (Life and Medical Sciences): Biology and genetics, Health, Medical information system

1. Introduction

When sitting down or standing up, a person’s head, neck and waist should form a straight line. The ears and the sides of the shoulders should be aligned in the correct position. Positions with the neck protruding cause herniated cervical disks and sitting down on a chair in a horizontal or lying-down position causes herniated intervertebral disks. In particular, great caution should be taken to avoid sitting down with crossed legs, as it is the biggest cause of twisted cervical spines. However, people who fail to do so may end up with bent necks and backs due to studying or using computers on a desk. This happens when people’s line of sight falls from eye level. Also,
having hunched backs when standing or walking has the most adverse effects on the cervical spine. It also puts pressure on the chest, which negatively affects the lungs and digestion.

However, with correcting bad postures, people who undergo growth and change can see improved growth as well as brain development due to brain cell activation. The relief of pressure and disruption from the nervous system can also help with the recovery of appetite, stamina and vitality. It can also prevent degenerative joint mutations and maximize flexibility, leading to prevention of unexpected injuries and maintenance of well-proportioned figures. In other words, position correction produces maximum effects from minimum efforts. In order to reflect such significance of position correction, we present the system which enables users to carry out continued position correction, by attaching various sensors to their bodies, checking their conditions, estimating most suitable positions, comparing them to initial positions to verify congruity and incongruity, and making the users aware of the findings. Moreover, this system aims not only to make the users aware, but also to help them eliminate the causes of incorrect positions, through the information management and analysis of the causes of persistent incorrect positions (An et al 2010; Hawes and Brien 2006; Lou et al 2006; Bazzarelli, Lou and Raso 2001). This study is organized as follows:

Section 2 introduces related researches, Section 3 describes the design and implementation of u-Wireless Body Area Network (WBAN). Section 4 discusses the validity of tests and results, and finally conclusions and plans for future studies are given in Section 5.

2. Related Work and Motivation

Mobile medical devices monitor physical conditions, and regularly check for abnormalities. In order to receive medical care, one has to use medical equipment in hospitals, recuperation centres and health centres. However, for people who need to receive medical care several times a day, such as diabetics, visiting hospitals several times every day can be very time-consuming (Lewis 2003). Also, repetitive treatments for relatively simple procedures can create great economic burden. Also, for sufferers of conditions that do not disrupt everyday life but require constant monitoring, such as heart diseases, the real-time check-ups in hospitals or recuperation centres can lead to decreased quality of life, narrowed scope of activity, and most importantly, economic burden. Hence, patients can use mobile medical devices to continuously check and manage their own conditions, connect the devices to mobile phones to send SMSs to saved numbers if problems and emergencies arise. Mobile medical devices can also be linked to medical institutions to be used in treatments. Current medical devices use not only chemical methods, such as for blood tests, but also physical methods such as measuring blood pressure, ECG, temperature and weight. Also, in order to ensure everyday mobility, they are produced in the forms of watches, rings, necklaces, belts, underwear, socks, shoes and hats, or so that they can be integrated to such items. In the near future, systems will be produced that use MEMS technology at µm levels, allowing them to be inserted into the body for monitoring anytime, anywhere (Katechakis et al, 2007; Kim and Moon 2009).

2.1 WBAN (Wireless Body Area Network)

Home mobile health care and wellness services include measurements and transmissions of personal biological signals and medical information, and WBAN is the core technology for this. WBAN is defined as the new transmission method that allows mutual communication of up to
several dozen Mbps between devices within three metres of the body, with the transmission distance from IEEE as standard, that are connected in a wireless network (O’Keefe et al 2005). Also, WBAN is classified into medical and non-medical, due to the unique transmission qualities of the inner human body and the need for bodily safety against transmissions (Kim and Hwang 2005). In other words, the presence of various components in the human body, such as water, fibres and bones, and the subsequent transmission losses, requires the selection of transmission band widths with minimal loss. In order to minimize the effects on the body, it is limited to a very low value. Also, it is divided into Wearable BAN, a network for nodes attached to the body, and Implant BAN, a network for implant-type nodes implanted into the body (Jang and Choi, 2008).

2.2 u-Health Care

The advent of various compact and mobile biological signal sensors, together with the organization of ultra high-speed communication networks and high-performance mobile communication devices, is foretelling an era of ubiquitous Health Care, or u-Health Care, where one can monitor one’s own health anytime, anywhere, and receive personalized services. In an ideal environment equipped with u-Health Care, users will be able to unconsciously monitor their health, and maintain optimal conditions by taking optimal actions at optimal times (Han and Jeong, 2006; Kim and Kang, 2008; Sim, 2009).

Also, such ideal u-Health Care environment is essential for the fast-approaching graying society and a well-being oriented society. Industry-wise, the u-Health Care market is expected to see rapid growth. According to research by Electronics and Telecommunications Research Institute’s Network Economic Research Team, the number of u-Health Care users will reach seven million in 2010, with a market size of 1,800,000,000,000 KRW. In America, NASA, HP, MIT and Vivo-Metris are using remote health monitoring systems and smart accessories that can communicate with PDAs and wearable computers to develop wearable or attachable biological signal sensing systems. The SELF (Self Environment for Life) system project, driven by the Intelligent Cooperative Lab at Japan’s Tokyo University, uses a telecommuting monitoring system that uses technology that can measure the conditions of respiratory organs (Kim, 2008; Rasmus and Crounse, 2005; Park et al, 2008).

3. u-WBAN Design and Implementation

3.1 u-WBAN Hardware

In this section, we present u-WBAN Hardware which can monitor a person’s cervical condition during sitting or standing, and help him or her to correct one’s posture. Figure 1 shows a flexible sensor measuring the angle of the head in order to determine one’s cervical condition, and Figure 2 shows a pressure sensor measuring both feet condition (http://www.tekscan.com).

There is a sensor that monitors the cervical vertebral condition by measuring neck angle, and one monitors position by measuring pressure on both feet. Firstly, the cervical vertebral condition monitoring sensor is produced using variable resistance according to the bending angle, as illustrated in Figure 1. It is installed to connect from the back of the head to the back of the neck, and is produced to decrease in angle when the head is tilted forward, and increase in angle when the head is tilted backward. The position condition monitoring sensor is produced using variable resistance according to pressure changes, as illustrated in Figure 2.
Figure 3 shows an MSP430 sensor board which supports ADC 4, digital 6 channels, and Zigbee, an integrated standard based on IEEE802.15.3. Using the sensor board, we can not only connect the flexible and pressure sensor multiplier but also get the values from the sensor wirelessly. Also, MSP430 supports mesh network so that we do not have to implement other network protocols. In this paper, we design the sensor board with thickness not exceeding 1cm using a lithium battery or a lithium polymer battery so that the sensor board is functional for a long time.

Figure 4 and Figure 5 show the sensor board with a flexible and pressure sensor in use. Sensor for monitoring cervical condition is as per the following. To monitor cervical condition, the sensor needs to be flexible and comfortable to wear. It also needs to locate the sensitive areas according to the degree of bending, and as the same device can give different measurement values depending on the attachment location, it is difficult to select suitable attachment positions. Hence, in order to measure cervical location determination, a sensor as illustrated in Figure 4 was developed. To
measure cervical angle, angles between shoulders and the back of the head need to be measured. However, when attached to the neck, it was not comfortable to wear and its sensitive reaction to neck movements led to inaccurate measurements. Hence, it was fixed to the back of the head, and as illustrated in Figure 4, it was equipped with a sensor that can measure the degree of bending and inserted with a support that can maintain an approximate angle of 15°, to allow measurements of cervical straightening, bending and tilting.

In order to estimate users’ positions, pressure exerted between both feet is measured. Whether standing, sitting or in unsuitable positions, both feet touch the ground to maintain position. When standing, weight is distributed evenly to both feet, and when sitting down, the weight of the legs pushes down on the feet. Therefore, it is possible to make estimations according to different positions, whether standing, sitting, sitting cross-legged or leaning on one foot. If pressure distribution between two feet is even as illustrated in Figure 5, one is sitting or standing in the correct position, and if pressure is not exerted on one or both feet the position is deemed unsuitable. Hence, pressure sensors were attached to the bow and the heal, where weight is loaded. Although weight is distributed to the whole foot, as the measurements are for position estimation, not for weight, they were set within the range in which no weight, weight when sitting, and weight when standing could be measured. As illustrated in Figure 5, the sensor was inserted inside, while the sensor board was inserted in the rear side or attached to the upper side of the shoes.

3.2 u-WBAN Software

In this section, we describe u-WBAN software including monitoring system based on PC, gateway, and hand-held monitoring system. The software uses the independently-developed cervical condition monitoring sensor to measure the degree of users’ spinal bending. By attaching sensors that can monitor whether or not the ears are aligned with the shoulders, the head is tilted forward, the back is hunched, etc., data according to each position is collected. By attaching sensors that can monitor whether or not the users are sitting down, standing, sitting down in suitable positions, sitting with the legs crossed, sitting on the edge of the chair and leaning back, leaning on one leg, etc., data according to each position is collected. The collected data is transmitted to handheld devices and gateways. The handheld device recalls the users’ standard condition values from the database and displays whether or not their positions are suitable, and
Figure 6: Overview of the system

Figure 7: Software program

Figure 8: Icons of estimated user position result
the gateway saves all the data collected from sensors into the database for information management. As illustrated in Figure 6, the sensors worn by a user measures his/her condition and transmit the data, while the gateway processes transmitted data to the display device for awareness training and to the database to be saved.

The position correction system program is as illustrated in Figure 7. An image notifies the users’ conditions on the upper left part of the screen as illustrated in Figure 8.

The simple design allows users to become immediately aware of their conditions. Also, there are gateway connections controls on the upper right part of the screen, and the transmitted data packets are displayed in the middle. Also, the sensor values are shown on the bottom. The transmitted data are saved on the database in pre-set intervals, and an alarm sounds to notify the user if he/she is in an unsuitable position. Also, as illustrated in Figure 7, by providing only image data when minimized, awareness training can continue simultaneously to other operations.

Figure 9 shows our application to apply hand-held device. Cognitive, monitoring, and set up mode comprise the system modes. In Figure 10, a person’s position presumed results show as an icon on the left of cognitive mode and values on the right of one. In Figure 11, monitoring mode shows changed values from each sensor as a graph on the left so that we can check the value in real time. Figure 12 shows that set up mode is used to set standards minimizing error rate from the mean values of sitting and standing 10 times.
4. Validity Testing and Results

In order to get the best test results from the previous work (Moon et al., 2011), data from specimens was collected for three months. To allow applicability according to user diversity, data for each position was measured 10 times in the pre-operation setting, and the estimation range was set using test average and standard deviation. Hence, as the settings are made in relative, not absolute, values, the same algorithm can be applied to light women and heavy men.

4.1 Cervical Condition Monitoring

Cervical angle according to position is displayed on the left, and data from the cervical condition monitoring sensor is received, saved, and the current condition displayed, on the right. In case of tilting forward, the values are fixed and therefore show close to zero deviation, but for upright or tilting backward, the values were different for each measurement and therefore showed deviation. To prevent interruptions caused by minute movements, a large permissible range needs to be set.

Using cervical condition sensor, Figure 13 Normal shows that the resistance maintains between 15kΩ and 25kΩ (error rate 2%) because bending strength is relatively small. Figure 13 Tilting forward shows that the resistance maintains between 9.8kΩ and 17.5kΩ (error rate 2%) with base bending strength. In Figure 13 Tilting backward, we confirmed that the resistance between 24.8kΩ and 32.5kΩ is the biggest change in the bending strength. Within those experiment environments, the accuracy of the cervical monitoring system can be confirmed in Figure 14.

In Figure 13, the average value is 19.8kΩ for normal, 13.7kΩ for tilting forward and 26.9kΩ for tilting backward. Cervical angle according to position is displayed on the left, and data from the cervical condition monitoring sensor is received, saved, and the current condition displayed, on the right. In case of tilting forward, the values are fixed and therefore show close to zero deviation, but for upright or tilting backward, the values were different for each measurement and therefore

![Figure 13: The graph of cervical condition in accordance with position](image-url)
showed deviation. In order to reduce generated deviation, we repeated the experiment 100 times and created relational expression in Figure 14.

Therefore, the permissible range to be determined as suitable is applied with ± standard deviation based on the average suitability value, and the permissible range to be determined as unsuitable is applied with each measurement value’s ± standard deviation value. After the application of the permissible range, awareness rate is 95.4% for normal, 97.8% for tilting forward and 91.9% for tilting backward, showing an average awareness rate of 98%. And the results of Figure 13 and Figure 14 can be summarized as in Table 1.

### Table 1: Comparison of the mean cervical condition monitoring

<table>
<thead>
<tr>
<th>User position after wearing device</th>
<th>Number of measurements</th>
<th>Average value</th>
<th>Standard deviation</th>
<th>Awareness rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>100</td>
<td>19.8kOhm</td>
<td>10.3</td>
<td>95.4%</td>
</tr>
<tr>
<td>Tilting forward</td>
<td>100</td>
<td>13.7kOhm</td>
<td>0.1</td>
<td>97.8%</td>
</tr>
<tr>
<td>Tilting backward</td>
<td>100</td>
<td>26.9kOhm</td>
<td>16.8</td>
<td>91.9%</td>
</tr>
</tbody>
</table>

### 4.2. Stance Condition Monitoring

Position condition monitoring sensor presumes user’s posture calculating pressure differences of both feet on the floor during sitting with one’s legs crossed, leaning on the left/right foot, and sitting or standing using sensor placed on feet. Figure 15 shows the distribution of pressure data according to position in a graph. Using the developed program, the users wore the devices for
eight hours per day for one month (20 days). Using the handheld device, data was continuously measured and saved. If circumstances forced users to take off the shoes, the data for the relevant time was not reflected in the average calculation value.

The pressure sensor subjected to weight load is installed on the bow and the heel of the foot, but for position estimation, only the data from the heel is used. When standing upright with the chest open, most weight is put on the heel of the foot, and when sitting down, the weight of the legs pushes down on the heels as well. Therefore, even if the bow sensors were eliminated, position condition monitoring was possible.

According to Table 2, just as was the case for cervical condition monitoring sensor, when different average values were calculated for each position, and ± standard deviation values were given as the permissible range, the awareness rate was 96%.

In order to test the effectiveness of the position correction system, in the first month, the awareness training function was switched off, so that although unsuitable positions may persist, measurements could be made without any awareness by the user. In the second month, the awareness training function was switched back on so that the user was immediately induced to correct position when unsuitable positions occurred.

For the third month, the causes of the unsuitable positions were analyzed using the data from the first two months, measures were taken, then data was collected for another month. Figure 16 shows the graph of daily averages for a month with the awareness training function turned off. Figure 17 shows the graph of daily averages for a month with the awareness training function turned on.
### Table 2: The result of stance condition in accordance with position

<table>
<thead>
<tr>
<th>User Position after wearing device</th>
<th>Average value (mV)</th>
<th>Standard deviation (mV)</th>
<th>Awareness rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing upright</td>
<td>R 1989.3</td>
<td>R 214.7</td>
<td>97%</td>
</tr>
<tr>
<td></td>
<td>L 1863.6</td>
<td>L 186.8</td>
<td></td>
</tr>
<tr>
<td>Leaning on the right foot</td>
<td>R 1202.7</td>
<td>R 221.2</td>
<td>99%</td>
</tr>
<tr>
<td></td>
<td>L 4095.0</td>
<td>L 0</td>
<td></td>
</tr>
<tr>
<td>Leaning on the left foot</td>
<td>R 4095.0</td>
<td>R 0</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td>L 1263.8</td>
<td>L 284.4</td>
<td></td>
</tr>
<tr>
<td>Sitting down upright</td>
<td>R 3982.2</td>
<td>R 33.3</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td>L 3998.2</td>
<td>L 25.5</td>
<td></td>
</tr>
<tr>
<td>Sitting with the right leg crossed</td>
<td>R 4095.0</td>
<td>R 0</td>
<td>91%</td>
</tr>
<tr>
<td>over the left</td>
<td>L 3230.6</td>
<td>L 585.5</td>
<td></td>
</tr>
<tr>
<td>Sitting with the left leg crossed</td>
<td>R 3562.5</td>
<td>R 392.6</td>
<td>89%</td>
</tr>
<tr>
<td>over the right</td>
<td>L 4095.0</td>
<td>L 0</td>
<td></td>
</tr>
<tr>
<td>Leaning back with buttocks on the</td>
<td>R 4095.0</td>
<td>R 0</td>
<td>100%</td>
</tr>
<tr>
<td>edge of the chair</td>
<td>L 4095.0</td>
<td>L 0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 16: The average one month data (did now use system)
Figure 17: The average one month data (used system)

Figure 18: The average one month data (removed cause)
According to Figure 17, the frequency of unsuitable postures did not decrease significantly following the application of the position correction system, but according to Figure 17, the accumulated time in unsuitable positions has decreased significantly. Moreover, analysis of the two graphs showed that for sitting, the highest frequency of unsuitable positions was for leaning back with the buttocks on the edge of the chair, and sitting down showed the highest frequency of unsuitable cervical conditions. Hence, data was collected for another month after changing the chairs to ones that support the waist and raising computer monitors and laptop computers to eye level.

Table 3 shows the daily data averages following the elimination of the causes of unsuitable positions. Compared to the daily averages for the first month, the accumulated frequency of unsuitable positions and the accumulated time have simultaneously decreased.

<table>
<thead>
<tr>
<th>Unit: frequency/time</th>
<th>0-1</th>
<th>1-2</th>
<th>2-3</th>
<th>3-4</th>
<th>4-5</th>
<th>5-6</th>
<th>6-7</th>
<th>7-8</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month</td>
<td>38</td>
<td>25</td>
<td>20</td>
<td>19</td>
<td>50</td>
<td>25</td>
<td>33</td>
<td>18</td>
<td>29</td>
</tr>
<tr>
<td>2 month</td>
<td>11</td>
<td>14</td>
<td>11</td>
<td>16</td>
<td>11</td>
<td>15</td>
<td>14</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>3 month</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3: Cumulative hours of data (not suitable position)

5. Conclusions and Future Work

The results of the position correction system showed that before wearing the devices, unsuitable positions were taken on an average of 42 times per every hour, for a total of 29 minutes. However, following the use of the devices, while the frequency of unsuitable positions decreased insignificantly to 39 per every hour, the accumulated time in unsuitable positions did decrease greatly to 13 minutes, a reduction of more than 55.1%. Moreover, many unsuitable positions were maintained for the sitting while leaning back with buttocks on the edge of the chair, sitting with the right leg crossed over the left, and the head tilted backward positions. Hence, uncomfortable computer chairs and the height of computer monitors are deemed to be the causes of continuous unsuitable positions. Countermeasures including the raising of computer monitors and laptop computers decrease unsuitable position frequencies and time to 16 and 5 minutes, a decrease in 61.9% and 82.7% respectively. As the data was collected over a relatively short period of time (three months), suitability testing and measurements for user habit changes were not carried out. A long-term study of at least one year duration needs to be carried out for continued awareness of unsuitable positions and for studying user habit changes. There is also a need for continued research using the pressure monitoring sensor attached to the bow of the foot, and for solutions to correct unsuitable walking habits.

For the future work, we plan to experiment using cases with more complex conditions. In addition, the exact position of the plantar pressure sensors will be positioned in the centre of the mount in order to reflect more realistic patients’ circumstances.

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References


http://www.tekscan.com/


Biographical Notes

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