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Smart Chair Cover for Posture Correction

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ABSTRACT

In this study, smart chair cover for modern posture correction is made by using more than 30 pressure sensors and the experiment is carried out in seven representative positions. It recognizes the postures through the pressure sensor, informs the user of the posture in real time, and accurately discerns the proper posture from the wrong by deep learning. In addition, the statistical data is visualized in the system, and when the ratio of improper posture is too high, the system informs the user of the possible danger of the improper posture and influence the user to correct the posture through stretching routine.

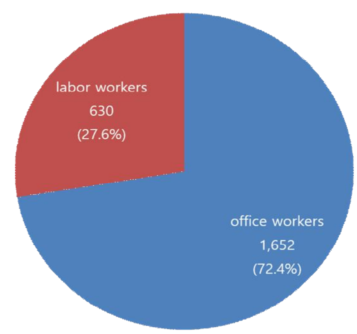
Key words: Internet of Things (IoT), Posture Correction, Smart Chair.

1. INTRODUCTION

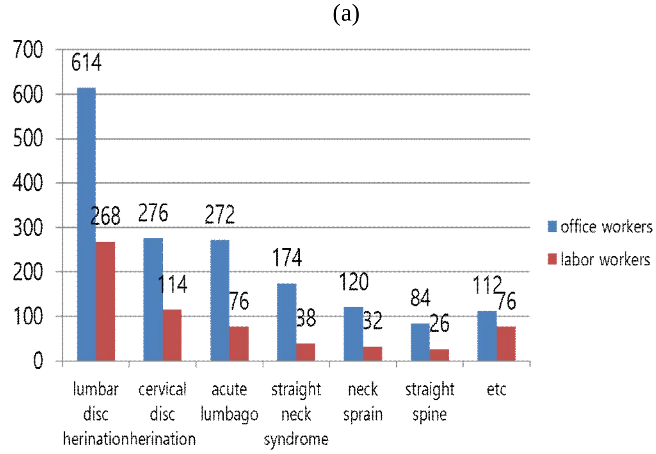
Many people in this modernized world spend about half of the day on the chair, mainly from increased office work hours and education. In addition, even children and elderly population spend more time sitting because of generalized household-held PC around the world [1]. To examine socio-demographical aspects and lifestyle, the National Health and Nutrition Survey is once conducted giving out questionnaires. When asked one of the questions, "how often do you spend your time sitting during the past seven days," of all 4806 respondent, 713 people answered less than 3 hours, 1274 people answered 3 to 5 hours, 1961 answered 5 to 10 hours, and 858 people answered more than 10 hours. The most frequently answered group is 5 to 10 hours, and the least is less than 3 hours [2][3].

Figure 1 depicts the results of a survey of 2,282 workers who had been treated at Jaseng Hospital of Korean Medicine for the past 3 months [4]. The panel (a) shows the percentage of the spinal cord disease patients by their occupation. The majority of patients who are first diagnosed with spinal cord disease in the hospital are office workers, a total of 1,652 and taking 72.4%. There are 630 labor workers, however, only contributing 27.6% of the total population who answered the survey.

The panel (b) of Figure 1 shows what is shown in the panel (a) in more detail, illustrating the ratio of office workers and labor workers in each spinal cord disease group. Lumbar disc herniation, the most common spinal disease, is what 614 office workers had for treatment. This is 129% greater than that of the labor workers of which only 268 are having it treated. This accounted for 37% of 1652 office workers who suffer from spinal cord disease as shown in panel (a).



(a)



(b)

Figure 1: Group of patients with spinal cord disease [4]: (a) Percentage of Spinal Disease Workers by Occupation, (b) the percentage of Occupation by Spinal Disease

Following lumbar disc herniation, neck disc is the second most common form which 276 office workers, 142% greater in number than that of labor workers, suffers and accounts for 17% of all office worker-patients. Greater number of office workers suffered from acute lumbago too. 16% or 272 office workers had it, which is 258% more than labor workers where only 76 people had it. 11% and 7% or 172 and 120 office workers suffered from straight neck syndrome and neck sprain. They continued to outnumber the labor workers by 358% and 275% each. For the straight spine, only 26 labor workers are diagnosed with it, while 84 office workers, whose number increased 223%, suffered from it. The number of office workers outnumbered in the last spinal cord disease group. For the other spinal cord disease or etc., 112 office workers responded positively whereas only 72(7%) of the labor workers did the same.

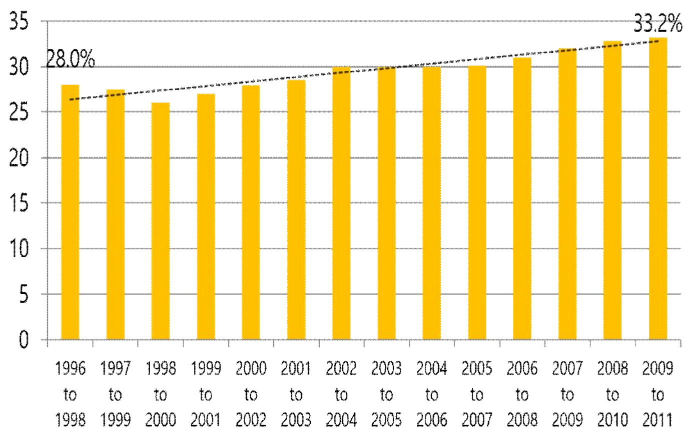


Figure 2: The trend in population with the musculoskeletal disease in the US [5]

Figure 2 shows the trend in the population of the spinal cord disease patients in the United States, and it can be noted that the spinal disease patients are appreciating not only in Korea but also in the US. The graph shows that the number of patients seemingly dropped from the mid-1990s but steadily increased until 2011 from the late 1990s. The number of patients increased by 19% from the initial point, 1996 to 1998, to 2009 to 2011, and increased 28% from the lowest the year 1998 to 2000.

This research uses a pressure sensor to measure various posture and understand them in the form of graphical data. These reduce processing limitation from parameters such as body type and sex and provide statistical analysis and solution through application to help the user improve the wrong sitting posture.

2. RELATED WORKS

Previous studies investigated ways to understand the sitting postures as the number of patients suffering from the spinal disease increased. These studies can be largely grouped into three by the mean it used, which are cameras, accelerometers, and pressure sensors.

In the case of research that uses a camera [6][7], like Figure 3, it mainly uses motion capture technology in which marker is attached to the joint of the human body to measure the motion that involves joint movement. The posture data of both legs is captured by the webcam without an IR filter, and the weight balance data is obtained from the PC with the balance board and the Bluetooth module. IR LED is attached on the bottom side of the experiment participants. Then, the flat mirror is placed on the opposite side of the camera to eliminate any possible special limit. The leg position is postulated from integrated data of weight distribution and the marker position. However, this approach is still restricted in that it must be performed in a limited space, and it is also difficult to use it in real-life settings. To overcome this issue, several technologies have been suggested for implementation such as a system that estimates and corrects an improper posture by a single camera. Nonetheless, this system lacks accuracy in distinguishing and recognizing the posture, and in measuring the lower part of the participant's body.

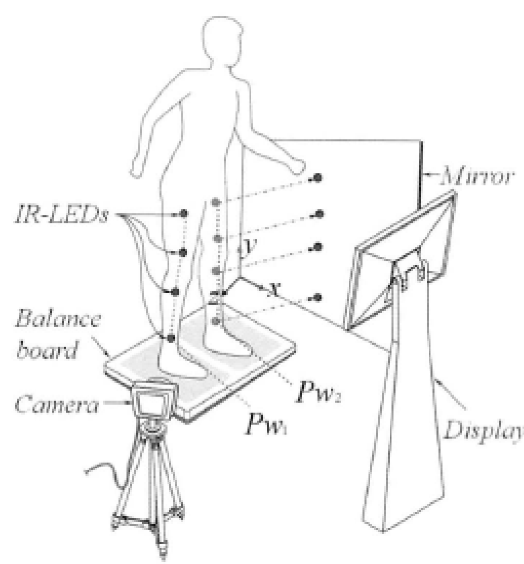


Figure 3: Installation of rehabilitation training based on motion capture technology [6]

Other studies use acceleration sensors [8][9]. Many previous studies conducted to monitor the difference in postures and activities through acceleration sensors, and others investigated ways to measure posture through acceleration sensors attached at a different site, distinguishing various activities. However, measuring movement through acceleration sensor is mainly focused on active motion rather than posture in activities such as sitting, standing, stepping up and down, walking and running. There are studies that tried to identify posture traits into two categories of proper and improper posture by attaching four inertia sensors. This research, however, only captures and confirms proper or improper postures, but fails to define what posture the user is assuming now, and what possible symptom can be caused by the posture, and to correct the improper posture to the better one.

In Figure 4, Some group [1] searched ways to classify the sitting position by attaching an acceleration sensor to the cervical spine. They put an acceleration sensor between the spine behind the neck and measured position change with respect to the gravitational acceleration to distinguish posture such as sitting straight up, sitting with neck bulging forward toward the monitor, lying back of the chair, sitting with a leg crossed, and sitting with an arm supporting the torso. The limitation of this study is, however, the inconvenience of attaching the sensor to the spine whenever the user sits down. In addition to the previously introduced research, some group also tried to classify posture by using built-in inertial measurement unit (IMU) neckband data. They attach the inertial sensor that can measure both acceleration and gyro on a single chip. As this method uses neckband that distinguishes posture by neck movement, it is difficult to grasp the posture of the lower body.

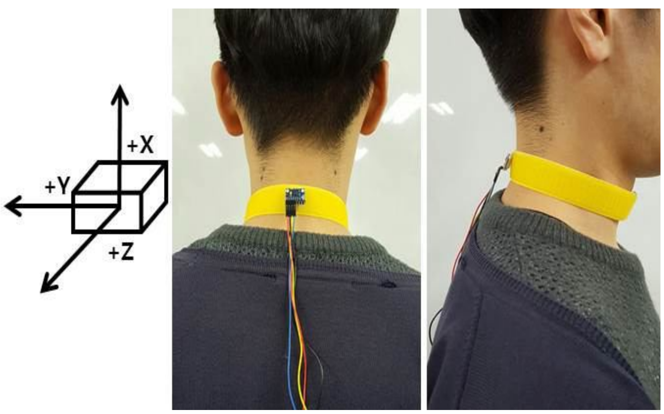


Figure 4: Insite of the attached sensor [1]

3. SYSTEM ARCHITECTURE

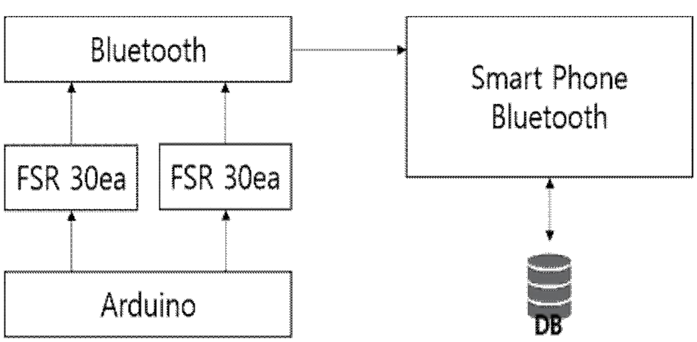


Figure 5: Schematic diagram of the system structure

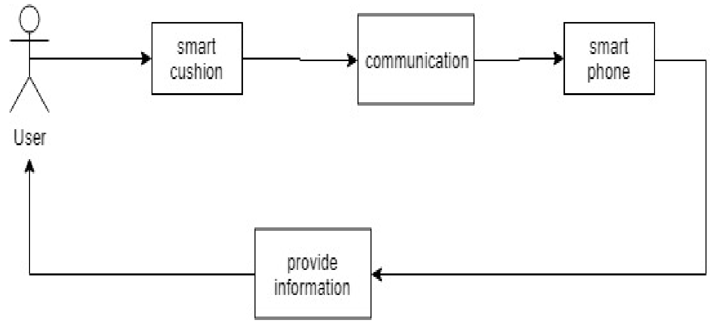
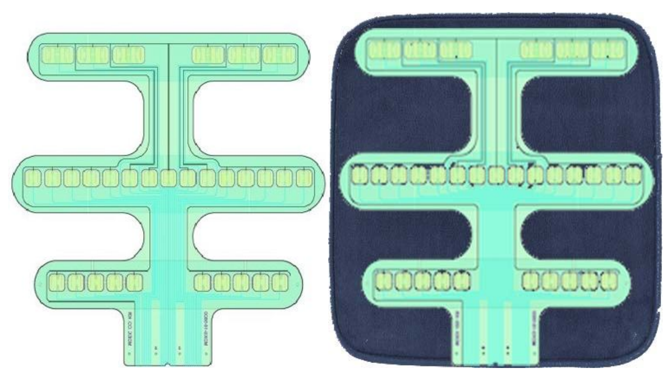


Figure 6: System flow chart

The smart chair cover cushion system's configuration and the flow chart are as demonstrated by Figure 5 and Figure 6. The smart cushion uses Arduino board and it's connected two pairs of 30 pressure sensors that measure pressure on the floor and waist respectively. The data is transmitted to the smartphone via wireless communication, and from this data, the posture is identified by the system. The posture identified is then compared to the value stored previously in the database, and then the appropriate posture is defined. Image and the text apt for the posture defined are transmitted to the smartphone while the system obtains real-time and accumulated data. In addition, when the system detects improper posture for a prolonged period of time, the phone vibrates and the alarm is notified through the smartphone, letting the user to follow the stretching routine. The system tracks whether the user performed the stretching for predetermined time period and guides the user to the next stretching movement or routine.



(a) (b)

(c)

Figure 7: Sensors and their configuration inside the cushion: (a) used the sensor, (b) Sensor in the cushion, (c) final sensor position in cushion

Our group used a total of 30 pressure sensors that are built in the smart cushion and connected to each other by a sheet as shown in the Figure 7 panel (a). The size is 380mm in width, 388mm in length, and 0.95mm thick, which is enough to cover the entire chair and very thin to cause any discomfort. The detection range of the sensor is from 5gf to 4Kgf, which allows various measurements feasible. The sensor (panel a) is connected to the Arduino and is built in the cover as shown in panel (b). Ultimately, the sensors are attached to the two parts, the back and the bottom part of the chair as shown in panel (c). When seated, the end and the middle of the chair receive the most pressure and the front part is subjected to relatively weak pressure. Thus, our group put the least number of sensors, six, in the front part. For the central part of the bottom of the chair, fifteen sensors are put, according to the data that from all four postures such as leaning right/left, sitting with right/left leg

crossed had most of the pressure exerted in the middle. At the end of the chair are ten sensors.

Figure 8: Prototype and prototype testing

The prototype that is shown in Figure 8 implements the hardware shown in Figure 5 by purchasing two cushions, connecting them, and attaching the sensors accordingly. The covers are then fixed to the chair used in the experiment. All the experiment mentioned in this paper is conducted using the prototype demonstrated in Figure 8.

3.1 Methods

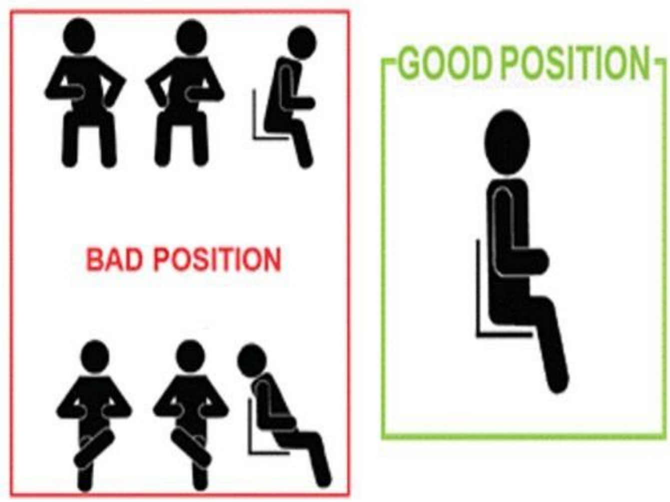


Figure 9: Data-derived images

Conventional orthodontic chairs are calibrated through physical pressure such as weight or body type or used pressure sensors to show RAW data value. In addition, our group uses visualization of acquired data to make it easier to convey information and used statistics to provide detailed and effective information to the users [10].

Figure 9 is an image representation of the data values transmitted from the pressure sensor. Bad Position is one of left-leaning, right-leaning, leaning forward, right leg crossed, left leg crossed, and backward-leaning posture respectively. Including the proper position (Good Position), the user will see a total of seven postures. According to the data value obtained through the pressure sensor, the appropriate image is displayed to the user, and the real-time posture live tracking and statistics are constructed based on the images.

Table 1 shows the demographic information of the experimental groups that carried out all in this paper. A total of 10 people is recruited from the experimental group, including 7 men and 3 women. All of them are recruited into disparate experimental groups. Especially for women who have the lease recruitment number, are carefully selected to be more representing participants. Our group recruited all three with different age, height, and weight profile. The male experimental group consisted of all different weight and different height. A to J represents Participant 1 to 10.

Table 1: Demographic information of the participants

	Sex	Age	Height(cm)	Weight(kg)
A	Male	27	171	77
B	Male	25	175	78
C	Male	26	180	93
D	Male	24	178	72
E	Male	27	182	98
F	Male	28	172	84
G	Male	30	177	74
H	Female	27	168	65
I	Female	28	163	68
J	Female	25	154	39

4. ANALISIS

Figure 10 demonstrates the experiment carried out by defining seven postures for 10 experimental groups with other sexes and body shapes. The average value of the pressure data of each posture group is expressed in a graph. A total of 30 pressure sensors is numbered and an average value is obtained by combining the sensor values at the corresponding numbers. The average value obtained is plotted against the sensor number. The X-axis represents the sensor number and the Y-axis represents the sensor value. In the graph, (a) is the front part of the chair, (b) is the central part of the chair, and (c) is the end part of the chair. In all graphs, sensors that lay between the legs are excluded because of the female participants. Female participants drew their legs together graphing a uniform and consistent graph while the male participants mostly sat with their legs open. This caused no input to be recorded on the sensor between the legs of the male participants and drew a sudden drop in their graph as shown in Figure 10. Our group decided that excluding them would convey more accurate observation.

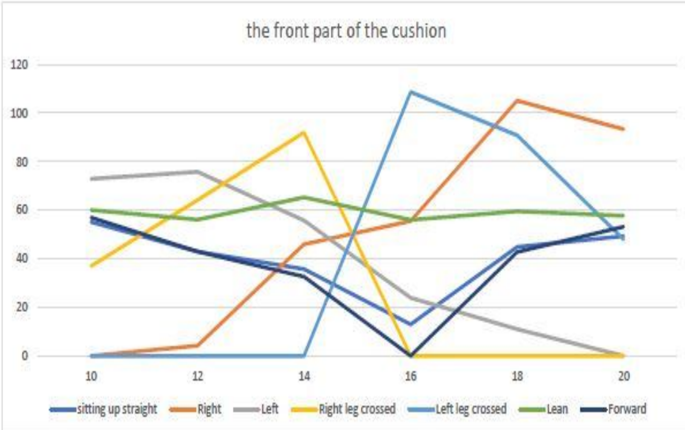
In the case of the panel (a), sitting straight, the entire graph is maintained consistently except for the sensor between the legs. Right-shifted postures increase the value from the left sensor to the right sensor gradually, while the left-leaning posture shows the sensor value rises from the right sensor to the left sensor, as opposed to the right-sided posture. The most obvious difference in pressure is the twisting of both legs. When the right leg is crossed, a strong pressure value is only detected on the sensor on the left side, and no pressure value is detected on the right side. Conversely, when the left leg is crossed, strong pressure values are recorded to the right sensor, and no pressure values are at the left sensor. In the backward-leaning posture, the pressure is higher than the proper posture and forward-leaning posture yet show a consistent graph with the value similar to the proper, sitting up straight posture.

In panel (b), both sides symmetrically show a constant graph for the proper posture and this is also true for the other posture such as right leg crossed, left leg crossed forward-leaning and backward leaning posture. However, the backward leaning posture has higher pressure than that of other postures. The most obvious difference between b is in the right-leaning position and left-leaning position. On the right side, there is no value of the left sensors and only the pressure sensors on the right side show a large value. On the other hand, the left-handed posture shows there is no pressure on the right sensor and that the pressure sensors on the left show large values. We can see on panel (c) that pressures from both sides come in uniformly. Among all, forward-leaning posture shows the characteristically lowest pressure.

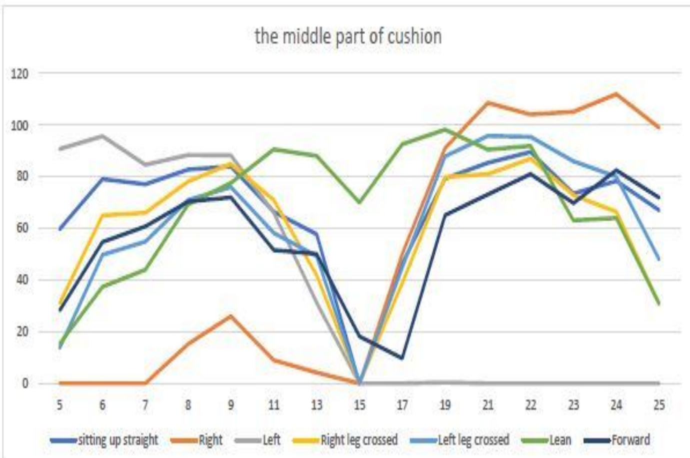
5. CONCLUSION

Smart chair cover for contemporary posture correction is expected to play a major role in improving the academic environment for all students and work environment as well as the sitting posture. To demonstrate this idea, our group used deep learning system to augment data from a small number of participants and confirmed effectiveness. Our group believes our suggested system can tell the exact posture of the users and correct the posture by the users themselves, which will be further bolstered by future research with various and expanded the experimental group.

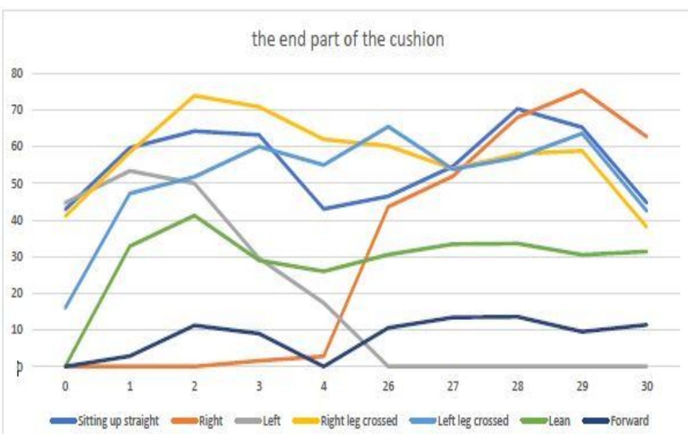
The hardware of our system is a chair cover which gives high usability and applicability, but it may seem quite loose. There could be an error where pressure data is misallocated to the system due to the dislocated cover. Thus, our group is going to redesign the cover so that it can be used in all kinds of a chair. Doing so, our suggested system of smart chair cover cushion is going to broaden the target subjects to children and adolescents.



(a)



(b)



(c)

Figure 10: Pressure data graphs: (a) pressure data graph for the front part of the cushion, (b) pressure data graph for the middle part of the cushion, (c) pressure data graph for the end part of cushion

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