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Assistive Devices to Help Correct Sitting-Posture Based on Posture Analysis Results

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***Abstract*—As many people spend a lot of time sitting on a chair, diseases such as turtle neck, straight neck, caused by incorrect posture have been increasing. Preventing these diseases and treating initial symptoms is helpful just by sitting properly. However, when people sit, their postures become disturbed without their knowledge. In this paper, we propose an assistive device in the form of a chair that helps people to sit properly and helps correct their sitting posture. The assistive device is equipped with pressure sensors capable of measuring the distribution of pressure applied to the floor of the chair, and an ultrasonic sensor capable of measuring the distance between the user's back and the chair back. First, an ultrasonic sensor and pressure sensors are used to determine the user's posture, and if the user's posture is not correct, an alarm is sent to the user to help the user to correct the posture by himself. Second, stretching information is provided according to the degree of distribution of pressure measured by the pressure sensors, and pressures are applied to the user's back with press-type cushions to help the user sit in a correct posture. In addition, even when sitting in a chair for a long time, an alarm is triggered to induce a person to rise from the chair. After implementing the system based on Raspberry Pi, each operation was checked. Furthermore, it was confirmed through the experiment participants that the proposed assistive device can help people correct their sitting posture.**

***Keywords*— Posture correction; posture analysis; press-type cushion; sensing chair; sitting posture.**

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I. Introduction

Recently, as many people use smart devices in a bad posture for a long time, sit cross-legged in a chair, or sleep in the wrong posture, diseases such as turtle neck, straight neck, back pain, spinal lateral flexion, and pelvic imbalance have increased [1], [2], [3], [4]. Data from the Korea Institute of Health Insurance Review and Assessment show that 44.4% of the Korean people treated with scoliosis - spinal cord bent sideways without showing normal shape - between 2011 and 2015 are teenagers between the ages of 13 and 16 [5]. In addition, it has been reported that call center employees who spend most of their business hours sitting down have more severe symptoms than general office workers [6]. Therefore, many studies have been conducted on a system that monitors and analyzes the user's posture using a camera or sensors such as flexible sensors or a pressure sensors [7], [8], [9], [10]. Some of these provide a posture correction function based on sensor information. However, most of the correction function devices are cumbersome to use or induce people to correct their posture by using alarms [11], [12], [13], [14].

Diseases such as the turtle necks, straight necks, and scoliosis can be treated by posture correction through strength training and exercise and lifestyle improvement in the early stages of the disease[15], [16], [17]. So students and office workers who spend a lot of time sitting on chairs need to sit in the right posture. It is recommended to sit deeply so that your hips are as close as possible to the back of the chair. In addition, it is better to straighten the waist and lightly pull the shoulders back to relieve strength, and place both soles of both feet on the floor. Also, sitting in one position for a long time is not good for your health, so it is good to change the posture every 30 minutes to 1 hour [18]. However, it is not easy to maintain a good posture unless people keep paying attention to sitting correctly in a chair and to rise from the seat regulary [19], [20]. Therefore, we propose an assitive device that not only sends an alarm to the user but also helps the user's sitting posture correction based on the results of analyzing the user's posture.

In the next session, the proposed sitting posture correction assistive device will be described. After explaining the results of the proposed sitting posture correction assistive device implementation and testing in Session III, we will conclude in Session IV.

II. Material and Method

Fig. 1 shows the conceptual diagram of the proposed sitting posture correction assistive device. It consists of a body mounted on a chair, six press-type cushions, six pressure sensors, an ultrasonic sensor, a vibration sensor, an LED, and a control device.

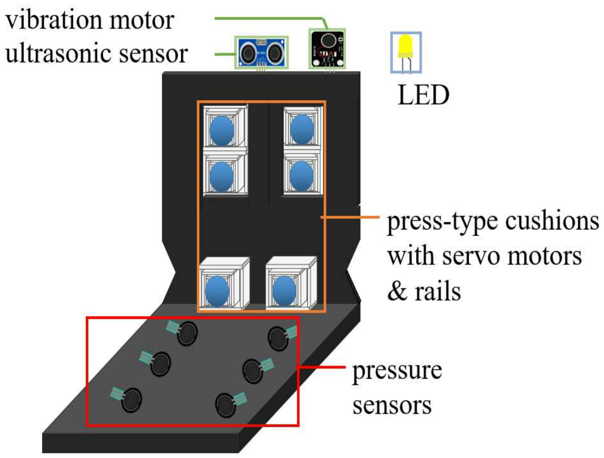
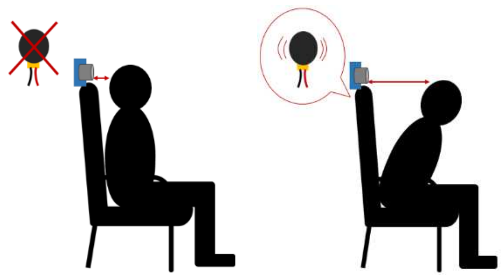


Fig. 1 A conceptual diagram of the proposed sitting posture correction assistive device

A. A system that induces the right sitting posture

When people sit in a chair, they sit in the right posture at first, but as time passes, their postures become disorganized without their knowledge. In particular, it is not easy to keep their back on the back of a chair. In this study, as shown in Fig. 2, we propose a system that allows people to correct their own sitting posture by notifying them by vibrating when they lean forward and their back moves away from the back of the chair.



(a) (b)

Fig. 2 Conceptual diagram of distance measurement and alarm system. (a) when a user sits correctly, and (b) when a user lean forward and his/her back moves away from the back of a chair.

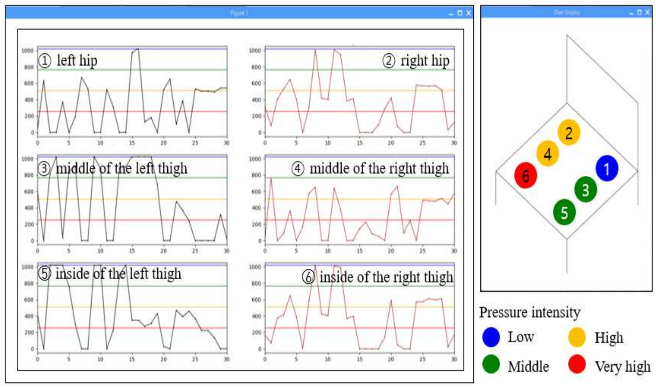
As shown in Fig. 1, an ultrasonic sensor and a vibration motor are attached to the upper back of the chair. A Raspberry Pi 3B based system analyzes the information of the ultrasonic sensor at regular intervals. And, when the user's back moves away from the back of the chair for more than a predetermined distance, the vibration motor generates vibration to notify the user.

Just as well as sitting on a chair, rising from a chair and stretching about every hour helps to maintain a normal posture and prevent shoulder and back pain. The system measures the amount of time the user sits in a chair using information collected from pressure sensors. When it is determined that the user has been sitting in the chair for an hour, the LED is turned on to inform the user. In our study, the LED is attached to the monitor that the user is viewing. However, it can be sufficiently implemented in other ways that the user can recognize the alarm, such as changing the position of the LED or using a speaker to notify it with sound.

B. A system that helps correct sitting posture according to the results of posture analysis

To analyze the user's sitting posture, six pressure sensors are attached to the cushion of the chair as shown in Fig. 1. The six pressure sensors measure the pressure on the left hip, the middle of the left thigh, the inside of the left thigh, the right hip, the middle of the right thigh, and the inside of the right thigh, respectively, when the user sits correctly on a chair. The system receives pressure sensor information and displays them.

Fig. 3 shows display screens showing the pressure distribution. Fig. 3(a) shows the pressure values measured by each sensor over time. From the top left, the pressure values on the left hip, right hip, the middle of the left thigh, the middle of the right thight, the inside of the left thight, and the inside of the right thight are indicated. Fig. 3(b) visually shows the average measured pressure values according to the position of the sensors. According to the degree of pressure intensity, it is classified into four levels - low, medium, high, and very high - and marked with blue, green, yellow and red, respectively.



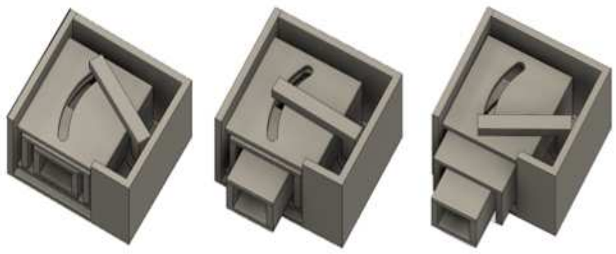
(a) (b)

Fig. 3 Display screens showing the pressure distribution (a) pressure measurements values from six sensors over time: From the top left, the pressure values on the left hip, right hip, the middle of the left thigh, the middle of the right thight, the inside of the left thight, and the inside of the right thight. (b) a visual representation of the average measured sensor values

The system then detects the symmetry of the left and right sides and the degree of tilt of the body. If the left and right pressure is measured asymmetrically, stretching methods such as a cat posture and a cobra posture to help with scoliosis are provided in pictures and text.

In addition, six press-type cushions are operated to help correct sitting posture. Fig. 4 shows the design of the rail of the press type cushion. A servo motor is attached to the inside of each rail. When the servo motor rotates, the rail is lengthened. At this point, the length of the rail extension depends on the degree of rotation of the motor as shown in

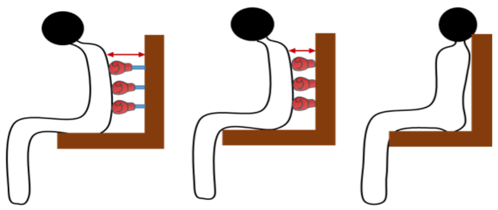
Fig. 4. When a servo motor rotates 0˚, the rail does not move. When a servo motor rotates 90˚, the rail is lengthened by half the maximum length. When a servo motor rotates 180˚, the rail is lengthened to the maximum.



(a) (b) (c)

Fig. 4 Design of the rail of the press type cushion. (a) When a servo motor rotates 0˚, the rail does not move. (b) When a servo motor rotates 90˚, the rail is lengthened by half the maximum length. And (c) when a servo motor rotates 180˚, the rail is lengthened to the maximum.

As shown in Fig. 1, six rails and cushions are attached to the back of the chair. After analyzing the user's sitting posture using six sensor information, the rails are lengthened to adjust the pressure applied to the user's back as shown in Fig. 5. If the user sits correctly, there is no need to correct the user's sitting posture, so the rail does not move as shown in Fig. 5(c). As a result of analyzing the values of the pressure sensors, if the user sits with the center of gravity to the left, it helps to achieve a correct sitting posture by pushing the left back using the left press-type cushions.



(a) (b) (c)

Fig. 5 Operation of the press-type cushions. (a) When a lot of pressure needs to be applied to the user's back. (b) When a little pressure needs to be applied to the user's back. And (c) when there is no need to apply pressure to the user's back.

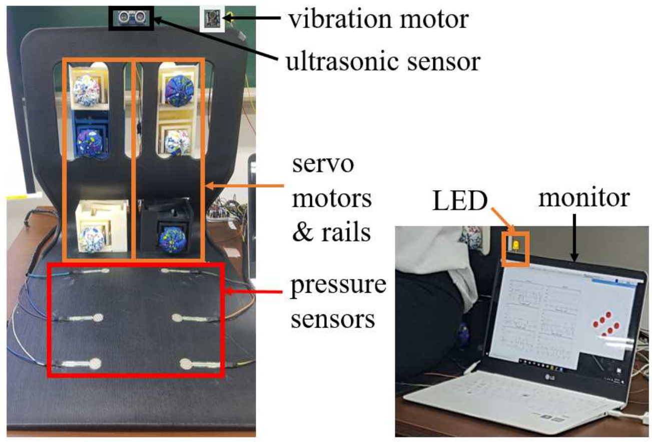
III. Results and Discussion

A. Implementation

Fig. 6 shows an implemented assistive device that provides posture analysis and stretching information and helps correct sitting posture. Devices for posture analysis and correction have been added to the assistive chair, which can be added to the existing chair.

Raspberry Pi 3B is used to control the entire system. An ultrasonic sensor is attached at the top of the chair to measure the distance between the user's back and the back of the chair, and a vibration motor is used to notify when the distance is greater than a certain distance.

Six pressure sensors are attached to the bottom of the chair. Each pressure sensor value is input to the Raspberry Pi 3B using a 10-bit ADC. By adjusting the magnitude of the resistance connected to the pressure sensor, when a person is sitting, the pressure at the hip is typically adjusted to be about 1000. Since the digitized pressure sensor value has a value between 0-1023, it is divided into four levels: 0-255, 256-511, 512-767, and 768-1023.

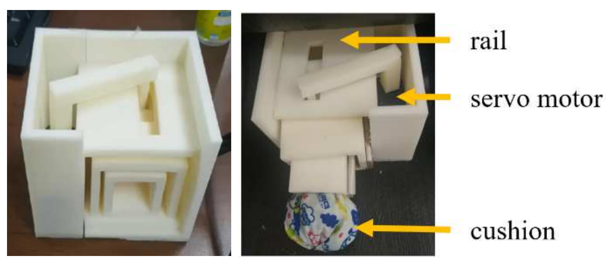


(a) (b)

Fig. 6 An implemented system (a) an assistive chair including devices for posture analysis and correction and (b) a LED and a monitor to display pressure distribute

As shown in Fig. 6(b), the pressure distribution graph and picture are implemented using python3. The sampling values of the pressure sensors over time are displayed in real time using the python3 library matplotlib. For the picture including the chair, the python3 library tkinter is used. Six circles are drawn on the canvas to indicate the six pressure sensors attached to the chair. The program reads the pressure sensor values and displays them in red, orange, green, and blue in order from level 3 (the pressure is the most) to level 0 (the pressure is the weakest), respectively. The values of all six sensors are displayed separately at the same time.

Fig. 7 shows a press-type cushion including a rail that is made with a 3D printer. A servo motor is included on the right side of the rail box and a cushion is attached to the end of the rail. The rail box is attached to the rear of the chair back. The servo motor rotates between 0˚ and 180˚, and the length of the rail is extended to a maximum of 5 cm. When the servo motor rotates, the cushion protrudes forward of the chair back, applying pressure to the user's back to help correct setting posture.



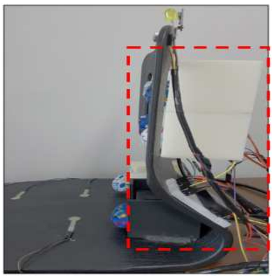
(a) (b)

Fig. 7 An implemented press-type cushion. (a) a 3D-printed rail box and (b) press-type cushion including a servo motor

As shown in Fig. 6(b), a LED is attached to the top of the monitor. The system uses the values of the pressure sensors to measure the amount of time the user sits in the chair continuously. However, the values of all six pressure sensors may become low due to brief movements such as sitting in a different position or standing up for other purposes. So, if all of the pressure sensor values become low within 30 s, it is not recognized as being out of the chair, and it is considered to continue sitting in the chair.

B. Function tests

Fig. 8 shows the operation of the press-type cushions. When the six sensors are evenly pressed, the cushions do not protrude as shown in Fig. 8(a), so it does not induce other changes to the user. On the other hand, if the sensors are unevenly pressed, the cushions protrude forward as shown in Fig. 8(b) and Fig. 8(C), which induces a change in the user's sitting posture.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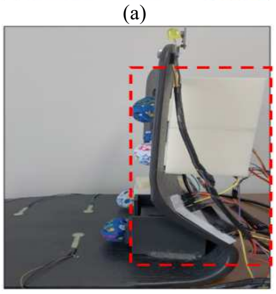
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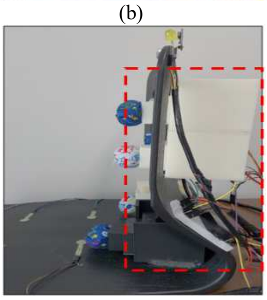
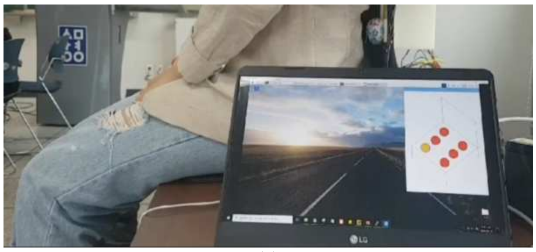

(c)

Fig. 8 Press-type cushions test. (a) When the six sensors are evenly pressed, (b) when the six sensors are unevenly pressed, and (c) when the six sensors are very unevenly pressed

It is confirmed that the system receives the values of the six pressure sensors, displays the measured values on the monitor, and changes the height of the press-type cushions according to the posture analysis results as shown in Fig. 9. First, pressure is applied to each sensor and the individual operation is checked by the values drawn on the monitor. As shown in Fig. 6(b), it is confirmed that the information of six sensors is simultaneously processed and displayed all graphic on the screen. And then, an experiment participant sits in the assistive chair and changes the posture to check the measured pressure values. As shown in Fig. 9(a), when the participant sits correctly on the chair, only the pressure in the right front part is high and the remaining five parts are very high. And, as shown in Fig. 9(b), when the participant sits with the right thigh above the left thigh, the pressure in the right rear part is marked as low. In other words, the center of gravity of the body is skewed to the left. So, as shown in Fig. 9(c), the press-type cushion on the left rushes forward and pushes the user's left back to help distribute the center of gravity to the right.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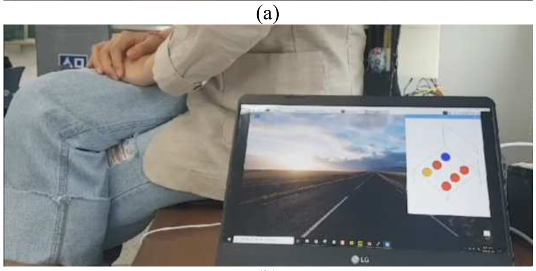
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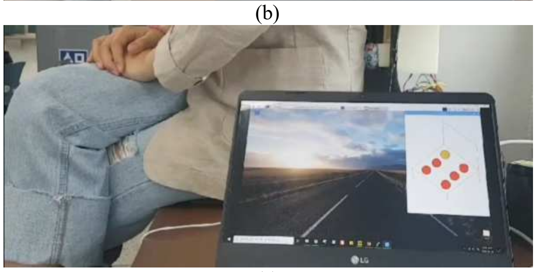
(c)

Fig. 9 Pressure distribution and cushion movement according to sitting position. (a) When the participant sits correctly. (b) When the participant sit with the right thigh above the left thigh. (c) The press-type cushion on the left rushes forward

When a user sits in a chair for more than one hour, the system to notify this using a LED is tested. However, the experiment is conducted by changing the time limit to ten minutes. In order to change the values measured by the pressure sensors, the experimenter changes his posture slightly in the middle of the experiment. As shown in the Fig. 10, the LED turns on 10 minutes after the user sits in the assistive chair. After the LED is turned on, the LED turns off when the user rises from the assistive chair and all six pressure sensor values are measured as low level during 30 s.

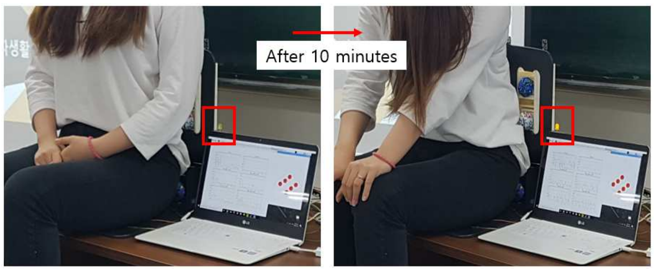

Fig. 10 Notification system test using a LED

Likewise, we also test notifying users with vibrations when they lean forward. The experimenter sits down with his hips attached to the back of the chair, and leaned his upper body down against a desk. In the experiment, vibration is generated when the distance from the ultrasonic sensor attached to the chair to the user exceeds 8 cm. The distance needs to be set to suit the user, taking into account the height of the user and the height of the backrest of a chair, etc.

TABLE I
PRESSURE DISTRIBUTIONS FOR THE SEVEN DIFFERENT POSTURES OF ALL PARTICIPANTS A-H

Posture/ Participant		Pressure intensity					
		hip	Left middle thigh	inside thigh	inside thigh	Right middle thigh	hip
1	A	3	1	3	3	2	3
	B	1	3	3	3	3	3
	C	1	3	3	3	3	3
	D	3	3	3	3	3	3
	E	2	3	2	3	3	3
	F	3	3	3	3	1	3
	G	3	3	3	3	3	3
	H	3	3	3	3	1	3
2	A	0	1	3	3	2	0
	B	1	3	3	3	3	1
	C	1	3	3	3	3	2
	D	0	3	3	3	3	1
	E	2	1	3	2	3	1
	F	1	2	3	3	3	1
	G	1	3	3	3	3	1
	H	1	1	3	3	3	1
3	A	1	2	3	3	1	2
	B	2	3	3	3	3	1
	C	2	3	3	3	3	2
	D	0	3	3	3	3	1
	E	1	3	3	3	3	1
	F	0	3	3	3	3	2
	G	2	3	3	3	3	2
	H	3	2	3	3	3	1
4	A	3	2	2	1	3	3
	B	1	3	3	3	3	3
	C	1	3	3	3	3	3
	D	2	3	3	3	3	1
	E	1	3	2	3	3	3
	F	2	3	3	3	3	3
	G	1	1	3	3	3	3
	H	3	3	3	3	3	3
5	A	3	1	3	2	1	3
	B	2	3	3	3	3	3
	C	2	3	3	3	3	3
	D	2	3	3	3	3	1
	E	2	3	2	3	3	3
	F	2	3	2	3	3	1
	G	2	1	3	3	3	3
	H	3	3	3	3	3	2
6	A	0	0	3	1	1	3
	B	1	3	3	1	3	3
	C	2	3	3	1	3	3
	D	1	3	3	2	3	1
	E	1	3	3	2	3	3
	F	1	3	3	2	3	0
	G	3	1	3	1	3	1
	H	3	3	3	2	2	3
7	A	2	1	1	2	3	3
	B	1	2	1	3	3	3
	C	1	2	1	3	3	3
	D	1	3	3	3	3	1
	E	1	3	1	3	3	3
	F	1	3	1	2	3	1
	G	3	3	1	3	3	3
	H	3	3	1	3	3	3

C. Experiment to collect data for posture analysis

In order to analyze the pressure applied to the six sensors according to the sitting posture in the chair, an experiment is conducted on seven postures with eight participants (A-H). The seven selected postures include:

- posture 1: sitting correctly in a chair
- posture 2: sitting on the edge of a chair
- posture 3: sitting with the upper body bent forward
- posture 4: sitting with the left foot twisted behind the ankle
- posture 5: sitting with the right foot twisted behind the ankle
- posture 6: sitting with the left thigh crossed over the right thigh
- posture 7: sitting with the right thigh crossed over the left thigh

As an example, Fig. 11 shows the pressure distribution for seven postures of experiment participant A. When A is sitting the right position on a chair, the pressure in the middle of the thigh is weak, and the left and right pressure is also asymmetric as shown in Fig. 11(a). As shown in Fig. 11(b), when A sits on the edge of the chair, of course, the pressure inside the chair is barely measured, and the pressure in the front of the chair is measured as large as when sitting the upper body bent forward as shown in Fig. 11(c). When sitting with the ankles twisted, the pressure at the hip area is measured significantly, as shown in Fig. 11(d) and 11(e), and the intensity of the pressure from the thigh is shown to be asymmetric. When sitting with thighs crossed, the intensity of pressure from the hip area is shown to be asymmetric, as shown in Fig. 11(f) and 11(g).

Table 1 summarizes the pressure distributions for seven different postures of all participants A to H. The intensity of the pressure is expressed as follows:

- 3: very high
- 2: high
- 1: middle
- 0: low

Although there is slight difference for each participant, the distribution of pressure according to each posture shows a similar tendency to the pressure distribution according to each posture of the participant A.

D. Posture Correction Test

Three of the eight participants who participated in the experiment for data collection are asked to use the assistive chair for one week, and then the effect of posture correction is checked.

Fig. 12(a) and Fig. 12(b) show the pressure distribution before and after using the proposed correction assistive chair, respectively, when participant A sits in the correct posture on the chair. Before using the assistive chair, the pressure in the middle of the thigh is weak and measured asymmetrically. However, after using the assistive chair, the pressure is strongly measured on all six sensors and symmetrically overall.

Fig. 12(c) and Fig. 12(d) show the pressure distribution before and after using the proposed correction assistive chair, respectively, when participant F sits in the correct posture on the chair. Before using the assistive chair, the pressure in the

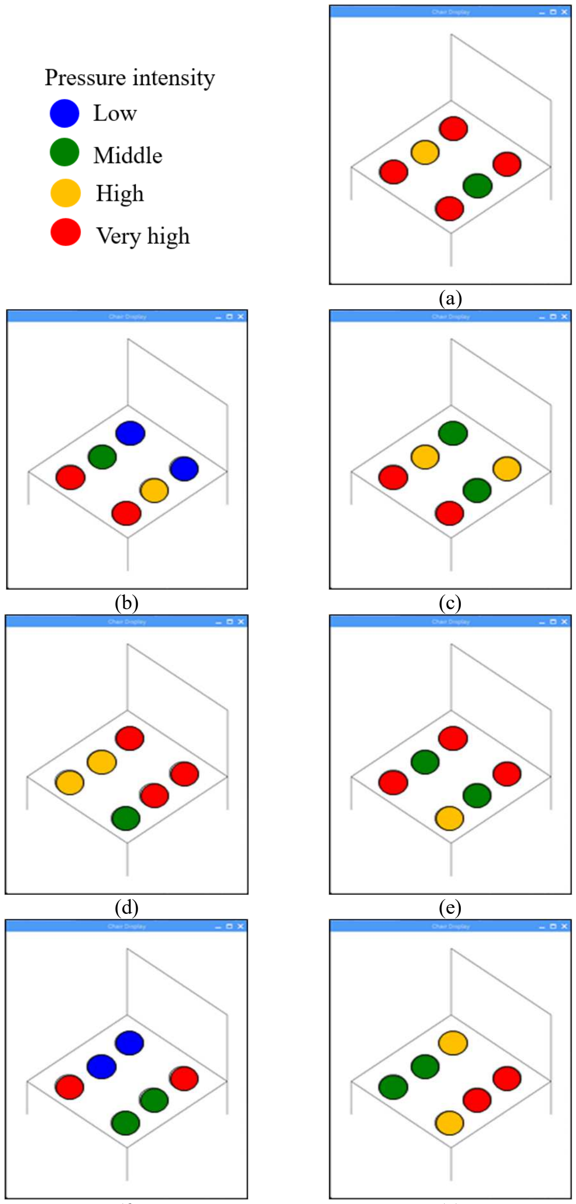

Fig. 11 Pressure distribution for seven postures of experiment participant A. (a) Posture 1. (b) Posture 2. (c) Posture 3 (d) Posture 4. (e) Posture 5. (f) Posture 6. (g) Posture 7

middle of the right thigh is weak and measured asymmetrically. After using the assistive chair, the middle of the right thigh is still weak and asymmetrical. However, it can be seen that the middle of the right thigh is stronger than before.

Fig. 12(e) and Fig. 12(f) show the pressure distribution before and after using the proposed correction assistive chair, respectively, when participant H sits in the correct posture on the chair. Like participant F, for participant H, the pressure in the middle part of the right thigh is weak and measured asymmetrically. Unfortunately, for participant H, the posture correction effect does not appear even after using the assistive chair.

As a result, two out of three people have a posture correction effect. However, these results are after the users have used it for only a week. Therefore, if the users use it for a longer period, the posture correction effect is expected to appear more pronounced.

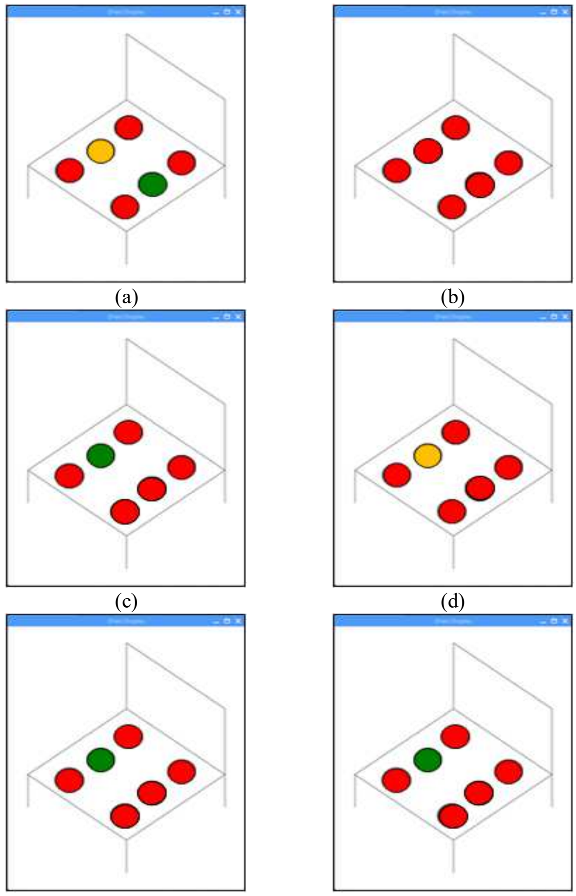

Fig. 12 Pressure distribution in the correct sitting position before and after correction. (a) Before correction of A. (b) After correction of A. (c) Before correction of F. (d) After correction of F. (e) Before correction of H. (f) After correction of H

IV. Conclusion

In this paper, we designed a posture correction assistive chair that helps people who spend a lot of time sitting on chairs to identify their sitting posture and maintain the correct posture while helping them to correct their posture. First, the distance between the user and the back of the chair is measured. When the distance is more than a certain distance away, it informs the user that the sitting posture is not correct. And when the user continues to sit in the chair for more than an hour, an alarm is generated to induce stretching. In addition, by showing the data values of the pressure sensors attached to the floor of the assistive chair in real time, it helps the users who are not aware of it to correct their distracted posture. And then, after analyzing the pressure sensor values, the system puts pressure on the back of the user with press-type cushions so that the user can sit in the correct posture. It also provides stretching information that can help with posture correction. Based on Raspberry Pi 3B, the system is implemented using a ultrasonic sensor, vibration sensors, a LED, pressure sensors, servo motors, cushions, and 3D-printed rails. Each function is verified, and the posture correction effect is tested through the participants in the experiment. Although the number of participants in the experiment is adequate, it is confirmed that the user's sitting posture could be corrected when using this assistive device. In the future, we plan to improve the accuracy of the system by utilizing tests through more experimental groups.

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