STUDY ON HIGH-PERFORMANCE SHOES FOR WALKING TRAINING

Kazuma KANEZAKI*, Yasuhiro HAYAKAWA**
Shogo KAWANAKA** and Shigeki DOI***

* Faculty of Advanced Mechanical Engineering
Nara National College of Technology
22 Yata, Koriyama, Nara, 639-1080 Japan
(E-mail: a0728@stdmail.nara-k.ac.jp)
** Department of Control Engineering
Nara National College of Technology
*** Department of Electrical Engineering
Nara National College of Technology

ABSTRACT

One of the most popular reasons that fall down of elderly person is a gap of the center of balance due to power down of muscle for aging. So we began to product new rehabilitation system that treat a gap of the center of the balance. We produced high-performance training shoes that shows status of walking balance. A method of communication that show status of walking balance is using tablet, Head Mounted Display and WiPort. The software of those devices are android because it is very easy to use. Further, we also produced walking assist system of human sole distribution from High-Performance Insole. We can change stiffness of High-Performance Insole corresponded to human sole distribution. So we can assist subject’s walking for rehabilitation. We evaluated newly produced High-Performance Training Shoes by using EMG to evaluate how direct assist system.

KEY WORDS

Rehabilitation, Pneumatics, Head Mounted Display, XBee, Air pressure

INTRODUCTION

In recent years, elderly people have been increasing. This is because that change of Japanese population is shown in Fig.1. According to Fig.1, it is cleared that the rate of elderly people to population of Japan is 33 percent by 2025. We predict that the number of fall down cases of elderly people increases.[1]

One of the most popular reasons that fall down of elderly people is a gap of the center of balance which is due to power down of muscle for aging.

Figure 1 The change of Japanese Population
Figure 2 shows trajectory of gravity point of both young people and elderly people in the walking motion. In the figure, solid lines show trace of a center of gravity, and broken lines show a center of sole of the foot. In the case of elderly people, motion of both solid line and broken line is shaking fiercer than young people. Therefore, elderly people are liable to fall down. We considered that realization of walking balance without a gap of the center of gravity position of foot is one of the solutions of fall down accidents.[2] So we propose a new rehabilitation system that improves a gap of the center of balance. The proposed system is constructed with special shoes, a display device and a WiPort. By using the High-performance training shoes, it is possible to show the status of walking balance. The system can make elderly people helping their walking.

**HIGH-PERFORMANCE TRAINING SHOES SYSTEM**

We developed High-Performance shoes that have following functions. Those are soft rubber actuator as a detector of sole pressure distribution, an insole with human affiliation and data sending system. Figure 3 shows appearance of the shoes. We try to assist elderly people’s prevention of fall down and rehabilitation by using these shoes. We explain about components of shoes from following chapters.

**Soft Rubber Actuator**

We developed soft rubber actuator that we call “Sponge-Core Soft Rubber Actuator” to detect sole pressure distribution and alter stiffness of insole. Figure 4 shows the structure of Sponge-Core Soft Rubber Actuator. Since sponge is covered with silicon, this actuator can change the inner pressure by blessing or exhausting air. Also this actuator has flexible surface and human affiliation is excellent.

**Insole**

We used Sponge-Core Soft Rubber Actuator to develop the insole. Figure 5 shows the developed insole. The insole is constructed with two types of elements. One is a detector type and the other is an assist type. With respect to the detector type, external force that acts on each element is measured by a pressure sensor. On the other side, air is charged into each assist actuator by using an air pump. Then, the stiffness of the actuator is changed. So we can assist subjects where position is biased. By using these actuators, we can assist both prevention of fall down and rehabilitation for elderly people.

Four detectors are equipped in the sole. Four areas that the detectors are placed were decided for mainly load distribution point of weight pressure. So we can evaluate how exerted the pressure on a surface of the insole. Depending on four detectors, there are four assist actuators. Further assist actuators are compatible with each detector. If detector captures pressure, we can find the forced position. So assist actuator that covers a detector changes its stiffness by air pressure as force. We apply this system for both prevention of fall down and rehabilitation.
Data Sending System

In order to show sole pressure distribution in real time, we send obtained pressure data to visual showing system. We equipped electrical circuit to obtain pressure data with shoes. Figure 6 shows an appearance of circuit. We send pressure distribution data that obtained by pressure sensor to display system by using XBee module which can use both send and receive the data. Communicating range of XBee is approximately 1.5 [m]. So we can construct communication field by using XBee.

We use Head Mounted Display and Android device as a display system. At first, we produce Wi-Fi field by using WiPort, a compact module including CPU, memory and so on. Therefore, we can use Android device as a display. Then, we use a Head Mounted Display that shows Android device’s display on glasses. Figure 7 (a) shows appearance of WiPort, (b) shows appearance of Head Mounted Display. Further, Figure 8 shows construction of data sending system. By using this system, we can show pressure distribution data as a graphic image. Figure 9 shows examples of pressure distribution data. Figure 10 shows structure of visual showing system.

Walking Assist System

We developed walking assist system by using assist actuators. Figure 11 shows construction of walking assistant system. At first, a pressure sensor which is equipped detection actuator catches load of insole. Next, spool valve which is corresponded the detection actuator is turn on when sensor catches the data. Third, air from micro air compressor is flowed in corresponded assist actuator. Finally, stiffness of insole is changed during walking.

EVALUATION EXPERIMENT FOR WALKING ASSIST SYSTEM

We examined effect of walking assist system. To evaluate effect, we examined both pattern of turn on the system and turn off the system. Subjects walked on the treadmill in 20[s]. We measured change of right knee joint angle and right hip joint angle by using goniometers. We also measured myoelectricities near main nerve parts to do walking. Table 1 shows information about subjects. Table 2 shows information about right insole. The number of table 2 correspond Figure 12. Figure 13 shows measurement parts of myoelectricities. Figure 14 shows walking sequence during experiment. Figure 15 shows each subject’s result of right knee joint angle. Figure 16 shows each subject’s result of right hip joint angle. Figure 17 shows each subject’s result of common peroneal nerve’s myoelectricity. Figure 18 shows each subject’s result of superficial fibular nerve’s myoelectricity. Figure 19 shows each subject’s result of inside sural nerve’s myoelectricity. Figure 20 shows each subject’s result of outside sural nerve’s myoelectricity. Figure 21 shows each subject’s result of inside tibial nerve’s myoelectricity. Figure 22 shows each subject’s result of outside tibial nerve’s myoelectricity. Figure 23 shows each subject’s result of saphenous nerve’s myoelectricity.
Table 1 Information of Subjects

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Age</th>
<th>Height [cm]</th>
<th>Weight [kg]</th>
<th>Inseam [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>20</td>
<td>178.4</td>
<td>58.4</td>
<td>86.3</td>
</tr>
<tr>
<td>(2)</td>
<td>20</td>
<td>167.5</td>
<td>65.3</td>
<td>77.4</td>
</tr>
<tr>
<td>(3)</td>
<td>21</td>
<td>172.3</td>
<td>64.2</td>
<td>79.1</td>
</tr>
</tbody>
</table>

Table 2 Information of Insole

<table>
<thead>
<tr>
<th>No.</th>
<th>Volume [m$^3$]</th>
<th>Inflow Velocity [m/s]</th>
<th>Full up Time [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.875</td>
<td>0.472</td>
<td>0.363</td>
</tr>
<tr>
<td>2</td>
<td>0.800</td>
<td>0.472</td>
<td>0.338</td>
</tr>
<tr>
<td>3</td>
<td>1.15</td>
<td>0.472</td>
<td>0.563</td>
</tr>
<tr>
<td>4</td>
<td>2.00</td>
<td>0.473</td>
<td>0.788</td>
</tr>
</tbody>
</table>

Figure 12 Allocation of Insole

Figure 13 Measurement Parts of Myoelectricities

(a) Direction of Goniometers (b) Walking Sequence

Figure 14 Information of Walking Experiment Sequence

(a) Result of Subject (1) (b) Result of Subject (2) (c) Result of Subject (3)

Figure 15 Change of Right Knee joint Angle

(a) Result of Subject (1) (b) Result of Subject (b) (c) Result of Subject (c)

Figure 16 Change of Right Hip joint Angle
Figure 17 Common Peroneal Nerve’s Myoelectricity

Figure 18 Superficial Fibular Nerve’s Myoelectricity

Figure 19 Inside Sural Nerve’s Myoelectricity

Figure 20 Outside Sural Nerve’s Myoelectricity
We compiled those results to consider the effect of walking assist system. Table 3 shows effective points for the assist system. We also show effective points as graphics. Figure 24 shows effective point for subject (1). Figure 25 shows effective point for subject (2). Figure 26 shows effective point for subject (3). According to Figure 16, subject (1) has bowlegged walking, subject (2) has pigeon-toed walking and subject (3) has drift walking. Figure 27 shows example of subject (a)'s pressure status during experiment. Assist SCSRA changed its stiffness together with detect SCSRA. These informations told us that people that have bowlegged walking or drift walking can use the system effectively.

<table>
<thead>
<tr>
<th>No.</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
<th>(f)</th>
<th>(g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>∅</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>2</td>
<td>x</td>
<td>∅</td>
<td>x</td>
<td>∅</td>
<td>x</td>
<td>∅</td>
<td>x</td>
</tr>
<tr>
<td>3</td>
<td>∅</td>
<td>∅</td>
<td>∅</td>
<td>∅</td>
<td>∅</td>
<td>∅</td>
<td>∅</td>
</tr>
</tbody>
</table>

∅… Effective Point
×… Ineffective Point
CONCLUSION

In this paper, we explained the exhibition system of walking balance and clarify the data of load distribution in the sole. In addition, we evaluated how shoes can reduce impact on human. Also we clarify the main moment of fall down of elderly people by using High-Performance Shoes.

Finally, we classified effective of walking assist system. So we can use the proposed system properly for both prevention of fall down and rehabilitation. But now we can use the system for limited walking pattern. In the future, we can reproduce new sharp of insole for people who have pigeon-toed walking.

ACKNOWLEDGEMENT

This research was partially funded by Grant-in-Aid for Scientific Research (c) (Project Number. 24500669). Additional support for this research was provided in part by SMC Co.Ltd.

REFERENCES
