# DEVELOPMENT OF A SIT-TO-STAND ASSISTANCE SYSTEM FOR PARKINSON'S DISEASE SUFFERERS
## *(Intellectual Handrail)*

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Abstract: A Sit-to-Stand Assistance System that can provide functional assistance in standing was developed. Two 650 mm stroke AC servo motor driven linear actuators were squarely combined. The handrail was installed at the intersection of these actuators. When the user stands from a chair, the handrail leads the user's motion. A personal computer (PC) is used to control the handrail motion, and force plates are placed under the feet. In this experiment the subjects were Parkinson's disease (PD) sufferers. Subjects were not able to stand up with a fixed handrail; however, they were able to stand up using this system without help.

## 1 BACKGROUND

Handrails are effective welfare tools that can provide assistance, such as walking and lifting motion, to the elderly and disabled. In addition, handrails are becoming widely used in many homes, and they have become the most basic item installed in house renovation. Previous research studies have also shown handrails are mostly used in restrooms, stairs, and bathrooms (Oshima et al., 2000; Takashima et al., 2005). To be used as a welfare tool in a house, it is necessary to fix the handrail onto the wall.

Therefore, it is not easy to reposition a handrail once it is fixed onto a wall. Previous handrail studies have focused primarily on finding what were the most suitable shape and placement of a handrail. However, a handrail that can give assistance in standing and guiding posture has not been investigated.

Standing-support welfare devices, such as "rising toilet seat" "rising chair" "rising wheelchair" have been already developed (Kamnik et al., 2005; Chugo et al., 2005; Uplift Technologies Inc.; TOTO LTD.). However, these devices give too much unnecessary assistance. Moreover, each individual user's symptoms, standing pattern, and degree of physical decline are varied. Naturally, these conventional standing-support devices cannot accommodate all these differences. It also should be pointed out that these devices which tend to lift the entire body "unnaturally" may unnecessarily promote physical strength decline.

## 2 PURPOSE

The purpose of this research was to develop an intelligent handrail that can give assistance in standing to PD patients and the elderly whose physical function has decreased. The motion of the handrail is guided by the user's posture, which is calculated from the 6 axes power sensors, placed on the handrail, and the ground reaction force sensors. In this manner, the motion of the handrail is synchronized with the user's posture while standing. In our previous studies, a handrail that could give assistance to users in standing was developed. (Nitta et al.; Daisuke et al., 2007).

It consists of two linear actuators which are crossed at right angles (Fig1). The handrail was installed at the intersection of these actuators. In this study, the development of this handrail was advanced further by the development of a control program.

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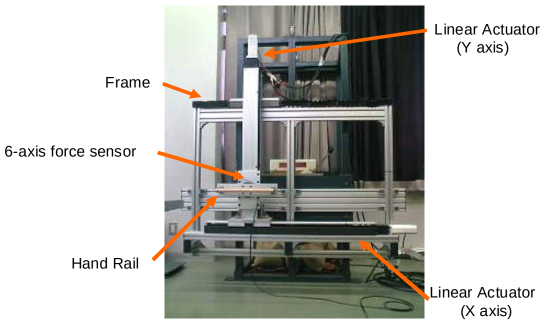


Figure 1: A handrail that could give assistance to users in standing.

## 3 METHOD

The effect of this control program, a trajectory generator device placed on the handrail, on standing movement of PD patients was investigated. In measuring the force that will be exerted on the handrail, the center of gravity trajectory, angle of the body, knee joint torque, load on the body at the time of standing, and the stability of the center of gravity were evaluated. In this manner, what would be an effective trajectory was investigated. In addition, the research aimed to compare the standing movement of two healthy adults with two PD subjects.

The average height of the two PD subjects is 1.60 (sd0.03)[m], and their average weight is 48.5 (sd5.5)[kg].The severity of their Parkinson's disease was stage 4 on Hoehn Yahr scale. Using a conventional handrail, it was not possible for the two PD subjects to stand.

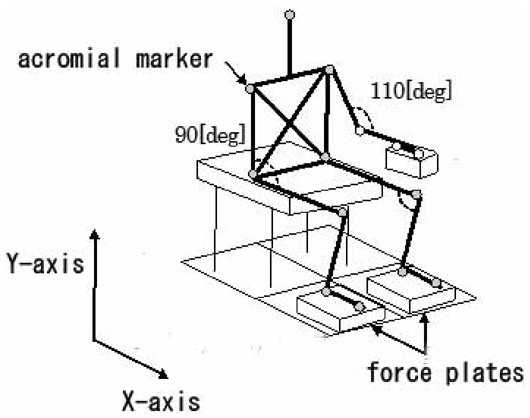


Figure 2: 14 optical markers.

As for the healthy adults, their average height is 1.73 (sd0.01)[m], and average weight is 70.5 (sd1.5)[kg]. The subjects were positioned on a height-adjustable stool. The initial lower limb posture was as follows: hip flexed 90 degrees and knee flexed 80 degrees.

The trajectory generator of the handrail was based on the ground reaction force data. The value of the vertical reaction force, derived from the right and left feet force plates, changes the trajectory of the handrail at a certain threshold. For this experiment, the following values 50[%], 70[%], 80[%] of the subjects' weight were assumed to be the thresholds. All subjects were subjected to the 3 thresholds. Healthy subjects did not use this intelligent handrail; however, they were told to stand slowly and statically

Each subject executed the experiment 2 times. As shown in Figure 2, a total of 14 optical markers were placed on the subjects (the head of the 5th metatarsal bone, lateral malleoluses, knee joints, hip joints, shoulders, top of the head, elbow, and wrist) and the handrail (the edge). Vicon motion analysis system (Oxford Metrics Company) was used for the measurement of the location of these body markers. 6 axes power sensors (Nitta Company) were placed on the handrail and measured the power exerted on the X-axis and Y-axis of the handrail.

Each set of vertical reaction force was established from the left and right feet force plates and the sampling frequency was set to 30Hz. Then, the angle of the hip joint, the location of the center of gravity, and the knee joints torque were calculated. For the PD subjects, measurement was conducted from the beginning to the end of the handrail movement. While the healthy adults were measured from the start of standing until the acromion marker stopped. Each segment of standing time, from start to finish, was divided, and the standing ratio time was established. When it is established that the power of the Y-axis of the ground reaction force, under the chair became 0[N], this indicates the point when hip is off the seat

## 4 RESULTS

Figure 3 shows an example of the handrail trajectory of the PD subjects. The starting point (0) is the initial position of the handrail. Among the 3 thresholds, the 80[%] threshold has the furthest trajectory. Figure 4 shows the center of gravity trajectory at the time of standing. The starting position (0) is when standing movement starts.

In addition, the distance from the starting point is normalized by the height of the subjects. In healthy adults, the center of gravity, initially, advances obliquely downward. Thereafter, it advances upward curvilinearly. In the PD subjects, when the threshold was set at 50[%], standing was not possible because

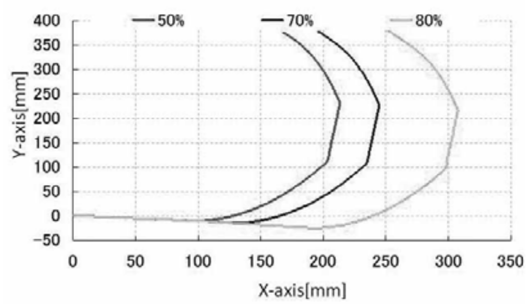


Figure 3: Examples of the handrail trajectory.

the center of gravity did not advance sufficiently to the supporting feet. When the PD subjects were made to move at 70% threshold trajectory, it was possible for them to stand; however, the trajectory of the center of gravity became linear. When the PD subjects' center of gravity was compared with the healthy adults' center of gravity, the former center of gravity advanced very little. On the average, the furthest center of gravity of the PD subjects was 37[%] of their body height. When the threshold is set at 80[%], the PD subjects could stand by themselves, and the handrail continued moving forward.

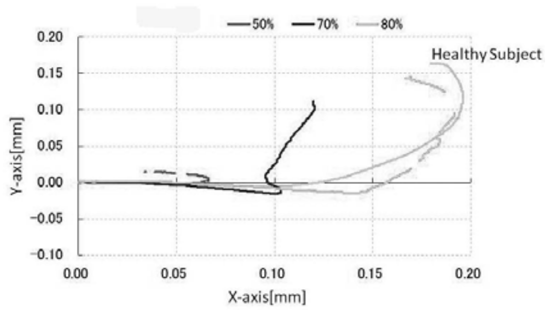


Figure 4: The center of gravity trajectory at the time of standing.

The furthest center of gravity location of this time was about the same with the healthy adults' value at the time of standing, which was 54[%] on the average. Figure 5 shows the knee joint torque of the PD and healthy subjects in standing.

Knee joint torque extension is indicated by negative value. A knee joint torque was normalized by the weight of the subject. The maximum knee joint extension torque of the healthy adults was greater in comparison with the PD subjects. When the threshold was set at 50[%], the knee joint torque of the PD subjects was smaller than knee joint torque at other thresholds because the center of gravity did not shift. In addition, at 70[%], and 80[%], there was a little difference in the knee joint

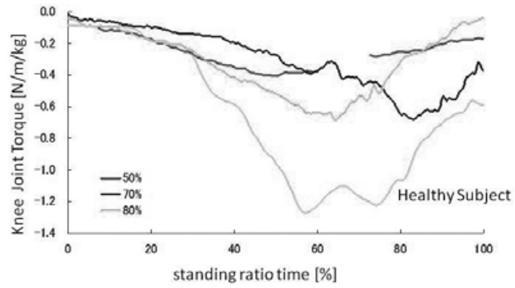


Figure 5: Knee joint torque of the PD and healthy subjects in standing.

torque of the PD subjects. Figure 6 shows the power exerted on the X-axis of the handrail by the PD subjects. In the case of 50[%], 70[%], 80[%]: At 50[%], power exerted on the handrail was the greatest.

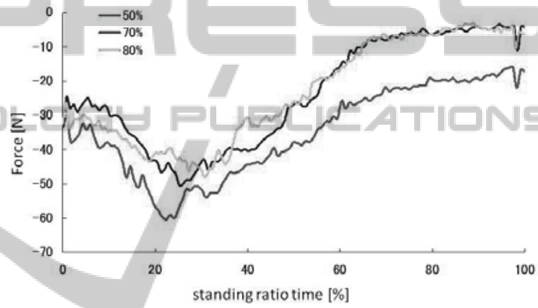


Figure 6: The power exerted on the X-axis of the handrail by the PD subjects.

However, at 70[%], 80[%], it was barely discernible. Figure 7 also shows the power exerted on the Y-axis of the handrail by the PD subjects. Positive value indicates subjects are pushing down on the handrail. At 80[%], the maximum power exerted on the handrail is almost half the power exerted at other thresholds. As mentioned above, the handrail trajectory was calculated from the ground reaction force. The finding shows that the 2 PD subjects, who could not stand with conventional handrail, were able to stand without help by using this intelligent handrail. Finally, we concluded that the center of gravity trajectory at 80 [%] threshold is the most effective because it is similar to a healthy adult's trajectory.

## 5 DISCUSSION

In healthy adults, the center of gravity trajectory plots a curve after hip is off the seat. Moreover, at this moment, the body inclines forward and moves vertically after hip off the seat. In addition, the

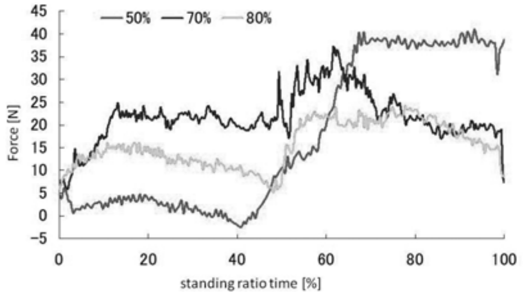


Figure 7: The power exerted on the Y-axis of the handrail by the PD subjects.

maximum location of the center of gravity was 54[%] on the X-axis, on the average. At this trajectory, a person is able to stand stably because posture stability is met. In addition, from this experiment, it was determined that the maximum extension torque of the knee joint was 1.19[N*m/kg]. When the PD subjects tried to stand using the intelligent handrail, standing was not possible when the vertical reaction force trajectory was set at 50[%]. This is so because the center of gravity did not advance sufficiently to the supporting feet. At 70[%], PD subjects were able to stand. However, the trajectory of the center of gravity became linear. It was thought that the timing when the subject's body began to move vertically was too soon. As a result, the handrail began to move vertically before the subject's hip was lifted from the seat. The body's movement observed here is different from the standing up movement of a healthy adult. When the handrail moved vertically, the center of gravity of the subject is still left behind the handrail. Therefore, it is thought that the weight of the subject was exerted on the handrail. Thus, the power exerted on the handrail was greater than in other conditions. When the threshold is set at 70 [%], subjects could stand but unstably because too much load is placed on the upper limbs and the center of gravity is left behind the supporting feet. When the threshold was set at 80[%], the PD subjects' center of gravity trajectory was similar to healthy adults', and thus, standing was possible. The physical movement resembled a healthy adult's movement, in which the body moved vertically after hip was lifted from the seat. The center of gravity position of the X-axis trajectory at the time the hip was lifted from the seat moved to the supporting feet. In addition, the knee joint torque of the extension direction became 0.94[N*m/sec] and was smaller than knee joint extension torque 1.02[N*m/sec], which is typically shown among the elderly who need assistance, including PD patients. From this study, it could be suggested that 80[%] threshold enabled the elderly and disabled individuals to stand stably. Finally, the application of this finding is the experimental production of a small intelligent handrail, shown in Figure 8.

Figure 8: The experimental production of a small intelligent handrail.

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