Study on the Gait Pattern of the Aged with Lower Limbs Orthosis

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Abstract: The purpose of this study was to analyze the gait motion of the aged with a lower limbs orthosis. The gait motion was analyzed with and without lower limbs orthosis using APAS 3D Motion Analysis System. The pattern of lower limbs motion was tracked based on four targets attached to the body of the subject. The targets were positioned at hip, knee, ankle, and foot.

The parameters measured were the displacement, the velocity, and the acceleration of the four targets. The improvement in the measured values on the displacement and the velocity of the four targets were small with the orthosis due to inconvenience of wearing it, but the increase in the acceleration was large due to the elastic force of the rubber actuator. Especially, the increase of the acceleration of foot with lower limbs orthosis seems to help the gait motion of the elderly.

Keywords: At least four keywords separated by commas

1. INTRODUCTION

The definition of an aging society by the United Nations was “A society in which 7% or more of the population is over 65 years old.” If the percentage goes over 14%, it is called an aged society. It is a highly aged society if the percentage goes over 20%. In the case of Korea, it was already an aging society with the number of the aged reaching 3.54 millions (7.4% of the population) in 2001. It was projected to be an aged society in 2022 and a highly aged society in 2032[1]. Especially in South Korea, it will take shorter time in becoming an aged society compared to some other advanced countries. As the ratio of the aged population increase, the nation is more concerned about elderly people and there should be a lot of researches going on for them.

According to S. H. Yoon et al [2], there is decrease in stride length and cadence and there is increase in walking support mainly when normal male elderly person (at most 87) walks in general velocity, not diseased. These walking patterns are not walking disorder. They are walking characteristics of normal degenerative system. The decrease of stride length and the increase of stride width is a way to keep the balance easily in elderly people walking. S. H. Yoon and co-worker have demonstrated this. Kerrigan et al [3] reported that flexion construction of hip joint and flexor muscle of the sole of the foot in ankle joint of normal elderly people are weak. Winter et al [4] found that there are not many differences in terms of cadence. But, step length gets shorter, double support time gets longer and push-off power decrease in normal elderly people. In the comparative research on walking characteristics between the young adults and the aged, these results were to walk in safer and more comfortable

The present study developed a lower limbs orthosis that helps an elderly who are unable to walk in a normal gait. In order to compare to characteristics between patterns with it and patterns without it, we made the new lower limbs orthosis and we analyzed the gait pattern of the aged with the lower limbs orthosis.

2. SYSTEM COMPOSITION

We have developed a lower limbs orthosis for gait motion for the elderly, and we analyzed gait motion of the elderly using APAS 3D motion analysis system in Ariel Dynamics Inc with and without lower limbs orthosis.

2.1 Hardware of 3D motion analysis system

The 3D motion analysis of the elderly was done using the parameters related to the displacement, velocity and acceleration of the targets on the body of subject. The 3D motion analysis system had three video cameras, special illuminators, video recorder, four targets, calibration tool, and fixation point. Video camera and special illuminator was used in photographing of experimental image. We also used halogen lamp (220V-300W) for the abstraction of the targets in special illuminator. The targets attached to the body of the subject were analyzed for the calculation of displacement, velocity and acceleration of each part of the body for the gait analysis of gait.

2.2 Software of 3D motion analysis system

The video footage of the experimental from video camera was transferred from hardware to software 3D motion analysis system. First, the video footage of gait motion using video camera was captured to computer by video recorder. The footage from the videotape, we trimmed one cycle of motion from the captured video footage for the gait analysis. The trimmed footage from the three video cameras was digitized. After the three digitized files transformed into a three dimensional file, it was passed through a filtering function, which contains, digital filter algorithm. The 3D motion files were shown in the display mode. In the display mode, we can construct stick figure, timetable, and analysis graph that told analysis on the gait motion of the elderly. Figure 1 shows displayed software system of 3D motion analysis in regular order.

2.3 Lower limbs orthosis

We developed a lower limbs orthosis that can assist muscular power of the elderly. The prototype of the orthosis is shown in Fig. 2. In the apparatus, we played artificial muscle

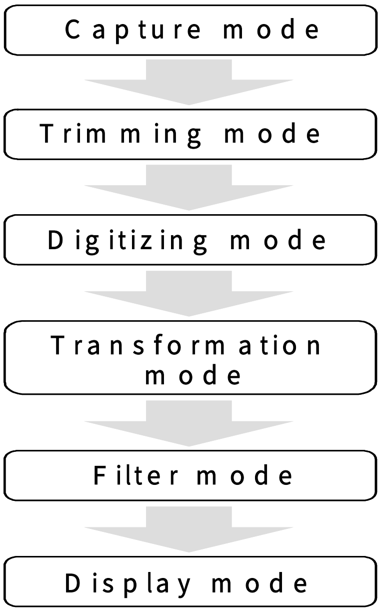


Fig. 1 The process of 3D motion analysis

that substitutes by lower limbs muscle in orthosis. We added set a protective device to the framework so as not to come off lower limbs orthosis from the weight in it. The basic framework can be divided into upper and lower by knee joint. To join the artificial muscle the framework, we devised and attached a jig to the upper of the lower limbs orthosis. The jig let artificial muscle move width and length direction like real muscle during flexion and extension motion in gait. The attached two artificial muscles can functions like rectus femoris and biceps femoris in lower limbs muscles in gait motion. Artificial pneumatic muscles made of a rubber bladders and a plastic net were used as actuators for the powersuit. Compared to hydraulic or electric actuators, they are soft and extremely light and have high power-to-weight and power-to-volume ratios. Therefore, they are quite safe and friendly to human bodies.

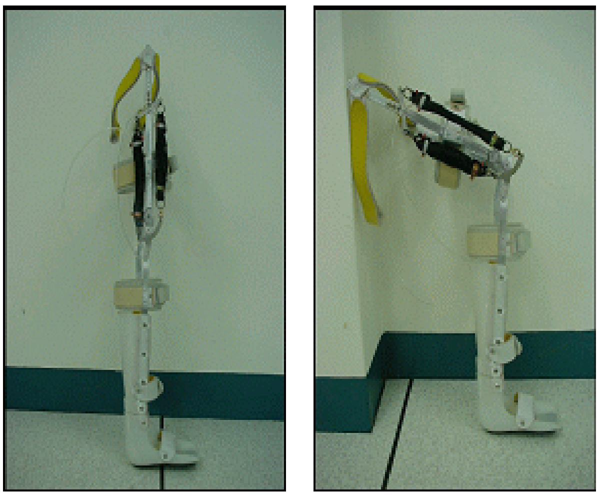


Fig. 2 Lower limbs orthosis

3. EXPERIMENTAL METHOD

In this experiment, the subjects were four normal elderly. The place for the experiment was dark and the subjects were dark clothes so that high rate of reflection in targets can be more easily detected in one gait analysis of the elderly. The gait analysis of the subjects was performed with and without lower limbs orthosis. Then, we analyzed each pattern of gait of the elderly.

The layout for the experiment of gait analysis is shown in Fig. 3. Walking trials were conducted on a linear track with 9m of length. The track was divided into three sections. The three sections were acceleration, constant speed and deceleration sections. The acceleration section was the initial section of the gait (initial 3m). The subjects were asked to maintain constant velocity in normal section (middle 3m). The last section of the gait was the deceleration section (last 3m). The motion data was collected at the middle part, constant speed section. The initial and the last sections were not considered in the experiment because of acceleration and deceleration [4]. So, the gait of the subject was captured by three video cameras only it the middle sections. The video cameras and the special illuminators were at the front, the right-45 degrees in the front part and the right 45 degrees in the rear part.

The subject familiarized with experiment by walking the whole track for three times before actual experiments. The coordinate system was such that the positive x-direction was the right side of walking direction, the positive y-direction was the upward direction, and the positive z-direction was walking direction [5]. We attached four targets in lower limbs to analyze gait pattern of the elderly. The targets were positioned at hip, knee, ankle and foot point. Each location was chosen

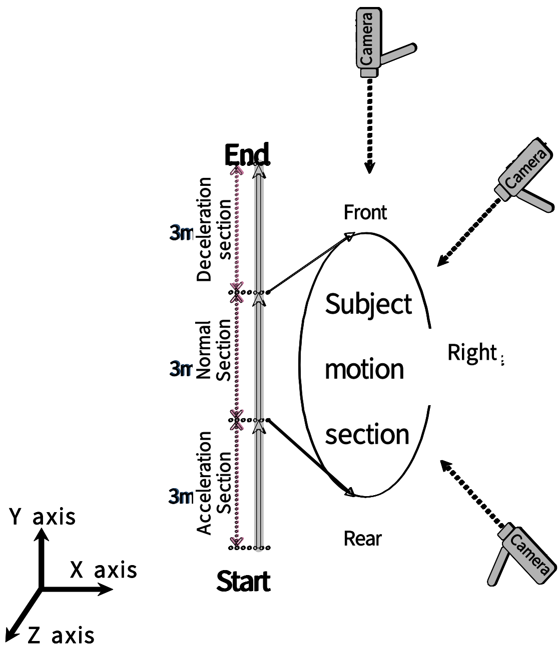


Fig. 3 Layout for the experiment of gait analysis

with the consideration of vital dynamics. We measured displacement, velocity and acceleration of the four targets for gait analysis of the elderly.

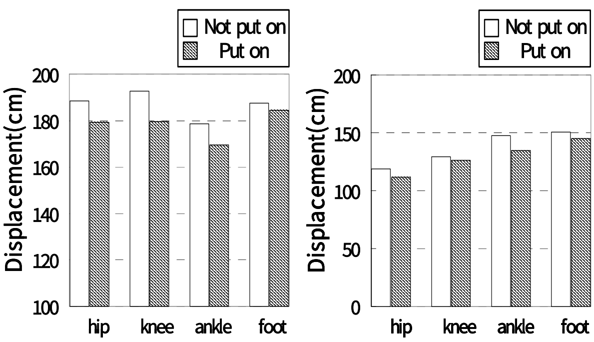
4. EXPERIMENTAL RESULTS

4.1 Comparison of gait pattern between with and without lower limbs orthosis

with the consideration of vital dynamics. We measured displacement, velocity and acceleration of the four targets for gait analysis of the elderly.

We analyzed the gait patterns with lower limbs orthosis with those without lower limbs orthosis in order to investigate the gait pattern of the elderly with lower limbs orthosis. We obtained the values of displacement, velocity and acceleration of the targets placed at lower limbs. The values were measured in X, Y, Z directions and absolute values. The values were converted into the average of each absolute value for the analysis of gait pattern.

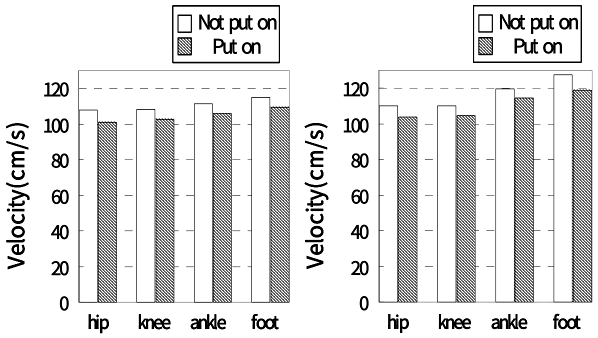
Figure 4~6 show the comparison between the measured values with orthosis and those without or this about the average value of the displacement, velocity and acceleration. The white column was not put on lower limbs orthosis and diagonal column was put on it. The displacement of diagonal column was smaller than white column in Z-axis and absolute displacement of whole targets. And in Fig. 5, the velocity value of diagonal column was obtained small value like Fig. 4. But acceleration was different from the displacement and velocity. The value of diagonal column, put on condition, was larger than white column, not put on condition. Especially, we can notice the high rate of the increase of the acceleration foot target with orthosis. The rate of increase in the foot target was the largest among the whole targets as shown in Table 1. The rate of increase in the acceleration of the targets at hip, knee and ankle targets were small. On the other hand, the rate of increase of the foot target was larger than others. What lift the end of toe in gait of the elderly was important factor. The rate of increase in foot target was concerned with gait motion of the elderly. From this point view, the lower limbs orthosis



(a) displacement in z axis (b) absolute displacement

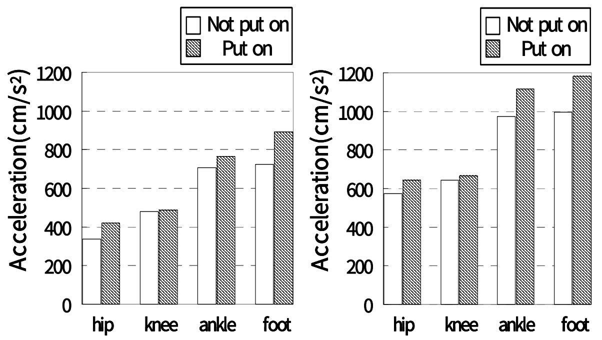
Fig. 4 Displacement of lower limbs target of the elderly

could fundamentally help the gait motion of the elderly. Because the property of the pneumatic rubber actuator in lower limbs orthosis was elasticity. Two cycle of gait are displayed in Fig. 7~9. The analysis of each targets on the lower limbs of the elderly with orthosis is shown in Fig. 7~9.



(a) velocity in z axis (b) absolute velocity

Fig. 5 Velocity of lower limbs target of the elderly



(a) acceleration in z axis (b) absolute acceleration

Fig. 6 Acceleration of lower limbs target of the elderly

Table 1 The rate of increase of acceleration with lower limbs orthosis (unit; %)

axis	Hip	knee	ankle	foot
Z	7.5	1.3	8.2	23.4
3D	12.0	3.7	14.8	18.9

Figure 7 shows a graph that displays the difference in the displacement in targets of the elderly with lower limbs orthosis. In lower limbs targets, hip and knee point was obtained small change, but the displacement of ankle and foot targets were measured large value. The velocities of the lower limbs of the elderly are shown with orthosis in Fig. 8. In this graph, there were two large velocity of ankle and foot target at initial part in two gait cycle. And there were three velocity of opposite direction (1~3) during stance phase. We regarded three velocity of opposite direction as reaction to step forward.

The last, Figure 9 was graph that showed difference of acceleration in targets of the elderly with lower limbs orthosis. There were four large value of acceleration in Fig. 9. The two value of in it showed positive (+) direction and the other represented negative (-) direction. The measured acceleration value could help gait motion of the elderly.

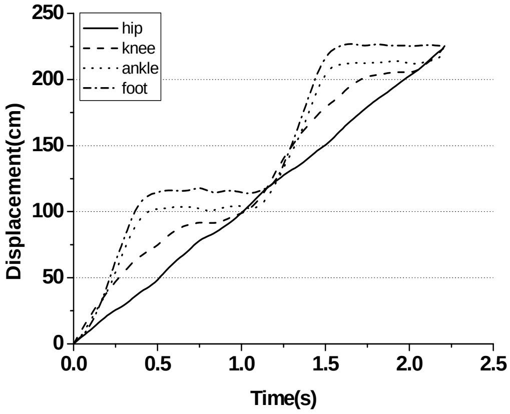


Fig. 7 Comparison of displacement of the elderly with lower limbs orthosis

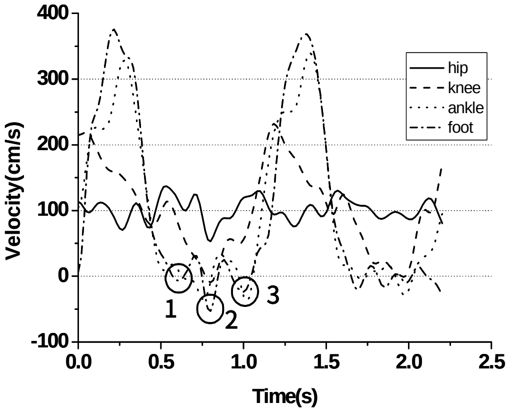


Fig. 8 Comparison of velocity of the elderly with lower limbs orthosis

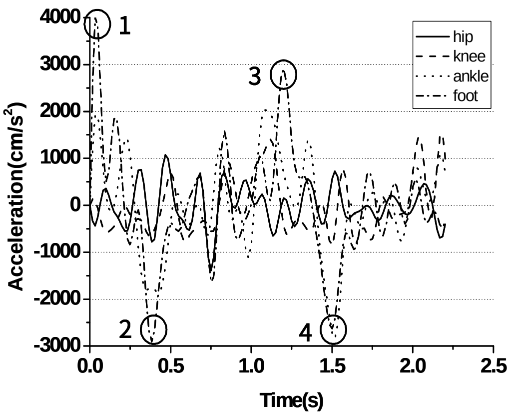


Fig. 9 Comparison of acceleration of the elderly with lower limbs orthosis

4. CONCLUSION

In this study, we compared the gait pattern when the orthosis was worn with that when the orthosis was not worn. The followings are the findings from the comparison.

1. The displacement of the targets with lower limbs orthosis was found smaller with the orthosis.

2. The velocity of hip, knee, ankle and foot targets with lower limbs orthosis was smaller than those without it. Whereas, the acceleration of the targets with lower limbs orthosis was larger than that without the orthosis.

3. The lower limbs orthosis using pneumatic rubber actuator could be found usefulness by increase of acceleration in foot target.

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