# Comparison of Changed Gait Pattern between Healthy Young Adults and the Elderly during Level and Uneven Inclined Walking

J.S. Choi, D.W. Kang, K.R. Mun, Y.H. Bang, M.S. Kang, H.S. Kim, H.S. Oh, and G.R. Tack

Department of Biomedical Engineering, Konkuk University, Chungju, South Korea

*Abstract*— **The purpose of this study was to compare the change in gait pattern of young adults and the elderly on the level and uneven inclined walkway. Fourteen healthy young adults (10 males, 4 females) and Twenty the elderly (13 males, 7 females) were participated in the experiment. The experiment was consisted of the walking in the level and uneven inclined walkway, and the motion data were collected and analyzed by using the three-dimensional motion analysis system during 2 kinds of walking conditions. The gait speed, ratio of gait phase (stance & swing), hip joint angle, knee joint angle, ankle joint angle and the trajectory of center of mass (COM) were used as variables for analysis. As a result, the gait change of the elderly group for uneven inclined walkway showed a difference from young adult group in the pattern of lower limb joint angle and the medio-lateral directional movement of COM. These changes by inclined and surface may affect gait pattern of young subjects as well as the elderly subjects. However, it is believed that the elderly were adapted to the uneven inclined walkway through different aspects from young adults and that may cause unstable movement pattern for the elderly gait. For the further analysis on change in gait pattern of the elderly, it is necessary to conduct a study with head movement, dispersion of attention and at the walkway under various conditions.**

*Keywords*— **Elderly, Gait pattern, Uneven inclined walkway, Center of Mass, Joint angle, Lower limbs.**

## I. Introduction

In general, the gait of the elderly shows a difference from that of young adults. To compare these differences in gait pattern between the elderly and young adults quantitatively, a study using gait speeds and temporal/spatial variables and the lower limb joint angle and moment [1, 2], a comparative study on the muscle activation using the electromyographic signal [3], a study using the difference in segment angle of lower limb and electromyogram of old female having the experience of hurt from falling [4], a comparative study using the fractal analysis [5], a study looking into the difference in toe clearance in the swing phase [6], a study inquiring into the movement of upper body at the time of gait [7], etc. were progressed in variety. The features of the elderly gait on the level ground in accordance with these previous studies were reported to have differences in the decreasing gait speed and stride length, difference in the range of motion (ROM) of the hip joint, knee joint and ankle joint, slope of the pelvis, etc.

Most of the previous studies, however, are the results performed by the gait on even level ground and on the slope way. Menz et al. (2007) reported that the gait change of the elderly is the adapted form to the reduced muscle and controllability of the elderly, and it plays the role of helping to carry out the comparatively stable gait [8]. That is, we may see that the result obtained through fixed experiment on gait on the even ground is the comparatively stable gait aspects of the elderly. In case of the falling of the elderly, since it is occurred when the body variables such as the sense, motor and regulating centers, etc. which involve in the body balance do not cause a rapid adaptation to the environment, it is necessary to compare with gait patterns in the not common walkway environment [9].

While assuming that the gait of young adult and the aged on the level ground are patterns suitable for each physical condition, it is necessary to inquire into the gait patterns being changed respectively under the other forms of gait condition. Therefore, the purpose of this study was to evaluate the pattern of change in gait variables of the young adult and the elderly at the aspect of kinematics through experiment on the gait on level and uneven inclined walkway.

## II. Methods

### A. Participants

Twenty persons (13 males: 72.4±5.2yrs, 164.5±5.4cm, 66.1±9.6kg, 7 females: 68.6±6.6yrs, 153.9±5.3cm, 60.6± 7.1kg) of the elderly (OG) and 14 persons (10 males: 26.3± 1.3yrs, 174.3±5.3cm, 69.5±9.5kg, 4 females: 22.8±1.0yrs, 160.5±3.5cm, 49.5±5.8kg) of young adults (YG) who has no career of musculoskeletal disorders in lower limbs for the last 1 year and walking normally were participated in this study. Before starting the experiment, subjects verified the purpose and content of this experiment and signed on the written consent of participation.

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### B. Experiment

All subjects performed walking on level and uneven inclined walkway for five times respectively. The artificial inclined walkway used for experiment was manufacture with wood, and it was manufacture to make its width to be 100cm, total length of inclined plane to be 240cm and the slope of inclined plane to be 20 degrees. To compose an unstable surface in the real-world, the artificial gravel mat was attached at the ground of slope (Fig. 1). Actually, although this mat did not affect to the extent to cause a big change in the gait motion of subject who wears shoes, it was sufficient to carve a stamp to the subject that the ground is not even.

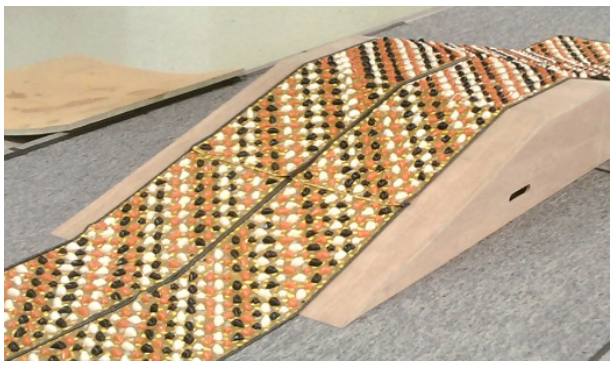

Fig. 1 Artificial uneven inclined walkway

The speed at which the subject usually walks comfortably with his/her usual daily shoes (excluding shoes for full dress) on used as gait speed, and made him/her sufficiently adapted to the experimental environment by carrying out the sufficient exercise gait before starting experiment. In this study, we used three-dimensional motion analysis system (Motion Analysis Corp., USA) consisted of 6 infrared cameras to acquire the motion data of subjects. Helen Hayes marker set was used and the sampling was made to be 120Hz.

### C. Analysis

All of the analysis variables used one cycle data of gait from the heel strike of stance phase of right foot to the heel strike of next stance phase of right foot in its analysis. In case of the uneven inclined walkway, one cycle from the stance phase of data where the first step going up to the slope surface is the right foot was used for analysis. In case of the marker data, rapidly changing data collection error was eliminated by low pass filtering with cutoff frequency of 6 Hz by using the secondary zero (0) delay Butterworth filter. The gait speed, ratio of stance and swing phases, joint angle of lower limbs (hip joint angle, knee joint angle, ankle joint angle) and the pelvic angle were used as variables for analysis [1, 7]. Among them, rotation of three planes (frontal, sagittal and transverse plane) only for the hip joint angle and the movement of sagittal plane only for the knee joint angle and ankle joint angle were considered. To extract variables, we used SIMM 5.0 software (MusculoGraphics, USA), and used Matlab ver.7.3 (Mathworks Inc., USA) for additional calculation of extracted variables. The independent t-test was performed by using SPSS 17k (SPSS, USA) software in the statistical analysis to verify the difference in variables between groups.

## III. Results

### A. Gait Speed

As shown in the <Fig. 2>, differences were occurred in the gait speed of YG and OG both on the uneven inclined walkway (Slope) as well as on the level (Level). There were differences in gait speed for both groups at the time of walking on the Level and Slope (YG:t=14.995, $p$=.001; OG:t=13.542, $p$=.001).

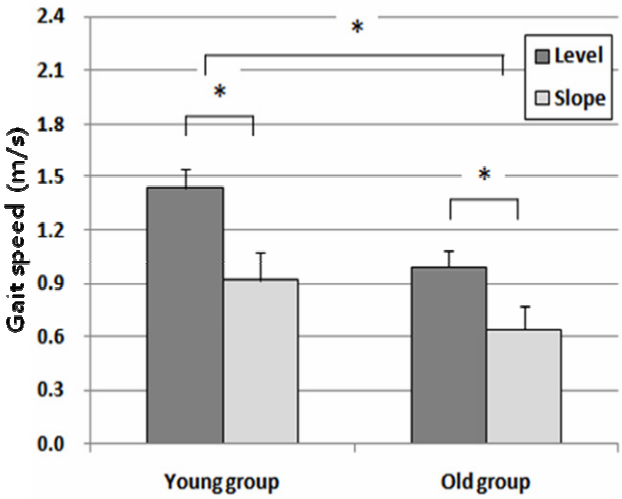


Fig. 2 Gait speed of both groups on level & slope walkway

### B. Stance Phase

As shown in the <Fig. 3>, the ratio of stance phase was maintained constantly for both groups regardless of the walkway conditions.

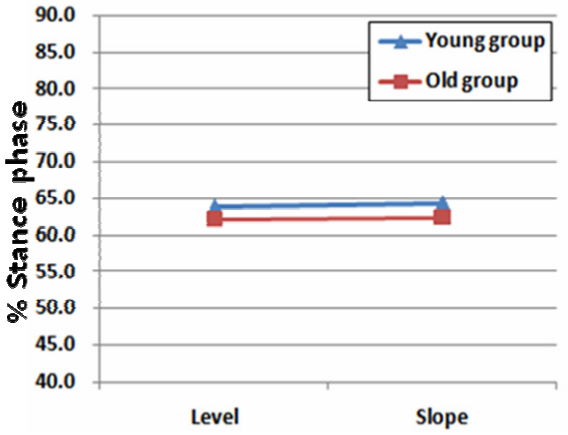


Fig. 3 Ratio of stance phase of both groups on level & uneven inclined walkway

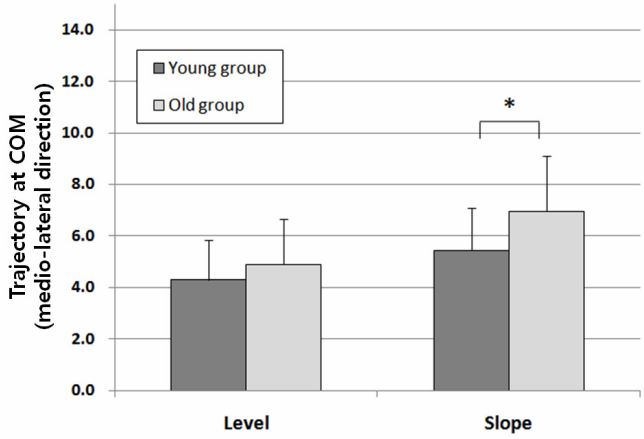


Fig. 4 Trajectory at COM (medio-lateral direction)

### C. *Joint Angles*

<Table 1> showed the range of motion of the lower limb joint during one cycle of the gait. In each group, the variables for lower limb joint angle where statistical differences were shown in accordance with the Slope were shown as the grey background.

Table 1 Range of motion on the lower limb joints

| | | Young group | | Old group | |
|---|---|---|---|---|---|
| | | **Level** | **Slope** | **Level** | **Slope** |
| **Hip joint angle** | **Add** | 17.96 (±2.89) | 16.02 (±4.89) | **20.61*** **(±7.98)** | **12.80*** **(±3.89)** |
| | **Rot** | 16.17 (±6.42) | 16.43 (±10.65) | **16.63*** **(±4.80)** | **13.45*** **(±6.10)** |
| | **Flex** | **45.54*** **(±4.48)** | **60.25*** **(±8.12)** | 44.52 (±9.85) | 48.80 (±12.27) |
| **Knee joint angle** | **Flex** | **70.68*** **(±5.45)** | **63.79*** **(±8.81)** | **65.54*** **(±10.03)** | **54.47*** **(±13.86)** |
| **Ankle joint angle** | **Flex** | **39.46*** **(±4.09)** | **31.45*** **(±6.87)** | 27.07 (±5.33) | 26.29 (±8.95) |

grey scale *: $p<.05$

### D. *Trajectory at Center of Mass (COM)*

<Fig. 4> shows the range of motion in the medio-lateral direction of COM. Although no difference in the range of movement of COM for two groups was shown, differences between groups were shown at the time of walking on the Slope (t=-3.510, $p$=.001).

## IV. Discussion

This study carried out the experiment on gait on the level and uneven inclined walkway to inquire into the change in gait pattern in accordance with the environmental condition of gait for the elderly, and compared the change form at that time with the result of young adult.

Although gait speeds of two groups were shown differently at each condition, each of the stance/swing ratios at each group was maintained constantly. This can be inferred that, although the speed in the direction of progress was reduced according to the climbing effect of inclined way, the control over ratio of stance phase and swing phase which is closely related with the stability of human body through single foot support was accomplished constantly, and it corresponds to the result comparing the gait of young adults and the elderly conducted by previous study of Noble & Prentice et al. (2008) by using the inclination angles of 3, 6, 9 and 12°[11].

In case of the range of motion of the lower limb joint, although an increase in the range of motion of other lower limb joints due to the restriction in the range of motion of hip flexion was expected for the elderly in the previous study done by McIntosh, Beatty, Dwan and Vickers (2006), but as a result of this study, the decrease in adduction and rotation of hip joint rather than increase in the range of motion of the flexion of other joints was noticeable (Table 1) [10]. In relation to this difference, the range of motion of the center of mass in the medio-lateral direction which is deeply related with the stability of body was shown bigger for the elderly group on the uneven inclined walkway unlike to the level walkway (Fig. 4). It is considered that this is the result possible to classify the gait characteristics of young adults and the elderly easily along with the study showing

the gait characteristics of the elderly on the uneven inclined way based on the inter-segmental coordination of lower limb joint angle [11].

In general, the muscle strength and balancing ability of the elderly are deteriorated in comparison with those of young adults, and accordingly, the fall risk is high [9]. Especially, the possibility of occurrence of the hurt from falling is high due to the lack of ability to handle against a case where any change in the condition of surface or condition of slope rather than walking on level is occurred [8, 10]. In relation to this, the result of this study verified other pattern of change of the lower limb joint by comparing factors for occurrence of change in gait aspects of young adults against gait condition (uneven inclined) with factors for change of the elderly. The ultimate purpose of this change of movement pattern of the lower limb joint is to obtain the stability of upper body (center of mass) or head, and the stable gait means the stable movement of the center of mass [8, 10, 12, 13]. In the comparison of the range of motion in mediolateral direction of the center of mass used in the inference of stable movement of body, the range of motion of the elderly was observed to be larger compared with that of young adults. That is, from the thing that the elderly who have weakened muscles and reduced regulating abilities on body show a rather large movement of the upper body, it can be inferred that the fall risk is aggravated due to it.

## V. Conclusions

The result of this study verified other pattern of change of the lower limb joint between two groups by comparing the change in gait pattern of young adults with that of the elderly against gait condition (uneven inclined walkway). In addition, from the viewpoint of regulating the movement of the center of mass which is the purpose of this change in lower limb joint, larger movement was showed in the elderly compared with in young adults. Through it, we proved the gait instability of the elderly indirectly, and further study is necessary to conduct an analysis on the movement of head, effect according to the dispersion of attention, and the experiment on adaptation to the surface with various condition, etc.

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Author: Gye-Rae Tack
Institute: Department of Biomedical Engineering, Konkuk University
Street: 322 Danwol-dong
City: Chungju
Country: Korea
Email: grtack@kku.ac.kr