Physical Exercise Goals of the Elderly through the Analysis of Kinetic and Kinematic Variables of Quick Walking—Results of the Koreans Elderly Using a Motion Analysis System

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Abstract: Since the global population is rapidly aging, social interest in the topic is increasing. However, there are not many studies on the elderly who are able to walk on their own, who make up the absolute majority of the total elderly population. Most studies and technological advancements are focused on either the development of assisting devices or on the elderly who use such devices or have a medical history. Therefore, this study analyzed the walks of 31 ordinary individuals of standard physical size and 31 elderly individuals. While there are studies on general gait and walk, there are not many on “maximum walking,” which is associated with a high risk of fall. For this purpose, a motion analysis system and the Ground Reaction Force Plate were used. The results of measuring and analyzing a total of 15 types of kinematic and kinetic variables as targets showed that the elderly experienced a reduced hike in the walking speed by approximately 5% during maximum walking when compared with normal walking. The variables related to balance were measured to be as high as 12%. Considering this, exercise of the elderly should be more focused on reinforcing variables related to balance, and in particular, emphasis should be placed on maintaining balance even when the walking speed increases.

Keywords: elderly; ordinary individuals; walk; maximum walking (walking quickly); kinematics; kinetics; comparison of changes

1. Introduction

Aging is a global phenomenon and is progressing at a fast pace in the advanced countries [1]. Hence, the scientific community is gradually becoming interested in the research on aging [2]. More activities are expected to be carried out by the elderly in this era of rapidly aging societies when compared with the earlier times [3]. Studies designed to support pedestrians and technical studies related to the elderly’s walk focus on the development of assisting devices targeting the elderly with disabilities [4–6]. Additionally, there are studies on ways of supporting the elderly’s walks using canes or railing [7,8]. However, the majority of the elderly who are able to engage in socioeconomic activities manage to walk on their own instead of receiving support from assisting devices. The elderly who are engaged in such activities are currently managing their lives just as the non-elderly by walking on pedestrian passages or crossing the street at maximum speed within the limited traffic signal duration. The travel necessary for economic activity, including commuting and simple leisurely travel, will continue to be maintained even with advancing age. This is especially true because of the increased average age of the socioeconomically active population, and in this process, the elderly will continue to use facilities used by the non-elderly at a high frequency. However, when compared with the non-elderly, the overall physical functions and cognitive abilities of the elderly are reduced as they age, leading to the deterioration of their muscular strength and balance [9]. Hence, the risk of falling in the same situation appears to be greater in the elderly than in the non-elderly [10,11], which can result in their death. In the U.S.,
the frequency of such cases is relatively high; 30% of the elderly experience [12] at least one fall annually. Such dangerous situations could occur more during a fast walk than a normal walk.

According to a previous study which measured and analyzed the characteristics of walking on the ground in the elderly and ordinary individuals using a motion analysis system, the Korean elderly were shown to have 70% of the walking ability of ordinary individuals by possessing 66.9% of the walking speed and 69.2% of the walking ability (walking rate) when compared to ordinary individuals. This result means that the elderly experience a reduction in the walking ability by 30% solely as a result of natural aging without any particular disease or injury. This finding implies that the use of walking facilities, which are being provided to cater for ordinary individuals, could lead to a high risk of fall for the elderly [13]. Such differences in characteristics are expected to occur more during a fast walk than an ordinary walk. However, no studies have previously been conducted on this topic. Therefore, this study measured the physical and walking characteristics of the elderly and ordinary individuals during normal walking and fast walking using a motion analysis system, and the changes in walking characteristics were examined based on the basic statistical results. As a result, the differences in the walking characteristics of the elderly when compared with those of the ordinary individuals were dramatic. Exercises are performed to maintain the elderly’s continuous activity, and in this case, reinforcement will be needed for the lack of walking and exercise ability. It is difficult to reinforce all of the overall gait ability, but it is necessary to supplement the essential ability, and this study attempted to derive it. In this study, the elderly were “healthy elderly” (>70 years old, no disease), and the ordinary individuals were “young adults” (19–29 years old). The gait ability was compared through actual measurements for the two groups.

2. Organization of the Walking Characteristics Analysis System

For examining the kinematic and kinetic data required for the analysis of walking characteristics of the elderly, a motion analysis camera system and a ground reaction force plate are generally used. These devices are especially used to execute an evaluation or analysis [14] of the safety of walking during ground or staircase walking and are also used for measuring and planning facilities or treatment [15] for disabilities.

This study used a motion capture system consisting of Raptor-3 and Eagle-4 and produced via motion analysis the motion analysis system. The detailed hardware and software compositions are shown in Table 1. For the motion analysis during ground normal walking and maximum walking, pedestrian passages were organized as shown in Figures 1 and 2. The total length of the pedestrian passage was 10 m and its width was 3 m, allowing it to remain unaffected by the surrounding facilities and enable straight-line walking.

| Table 1. Measuring device and analysis system. |
|-----------------------------------------------|
| **Device** | **Model** | **Manufacturing Country** |
| Hardware  | CCD Camera | Raptor-E and Eagle-4 | USA |
|           | VCR       | Gopro | Korea |
|           | Force Plate | 9260AA6 | USA |
| Software  | Cortex | ver. 6.0 | USA |
|           | Othotrack | ver. 5.0 | USA |
|           | SPSS | ver. 21.0 | USA |
For the motion analysis, 4 Raptor-E cameras and 8 Eagle-4 infrared light cameras were used. For the arrangement of the cameras, the height and angle were adjusted to allow the filming of at least 3 markers which would be attached to the bodies of the testers to facilitate motion analysis from all positions. The filming speed of each camera was set as 120 frames/s, and the shutter speed was 1/1000 sec. For ground reaction force (GRF), 1 Ground Reaction Force Plate (Type 9260AA6, 600 m × 500 mm × 50 mm) from KISTLER was laid at the center of the pedestrian passage (at 5 m), which was then covered with a mat identical to the pedestrian passage to ensure that the tester would not be aware of it. The acquisition rate of GRF was set as 1200 Hz, and for the synchronization of the motion analysis camera and the Ground Reaction Force Plate, the starting points of both devices were synchronized using an electrical sync. The coordinate date extracted from the video was smoothened using a secondary Butterworth low pass filter, and the cutoff frequency used was 6 Hz. The panoramas of the motion analysis system and the used system are shown in Figures 1–5.
3. Characteristics of the Target in Measuring the Walking Characteristics

The walking characteristics of the elderly and ordinary individuals were measured on a flat area during normal walking and maximum walking. The targets were 31 elderly and 31 ordinary individuals who were recruited by selecting individuals who met the average physical sizes [16] of Koreans and were >70 years of age or between 19 and 29 years of age. In Korea, “research excluded from human research under the Bioethics Act” is regulated. In accordance with Article 2, Paragraph 2 of the Enforcement Regulations, the following cases are not included in human research under the Bioethics Act. Participants in this study participated in the measurement after filling out the consent form with this explanation.

The average physical sizes of the subjects who participated in the measurement of walking characteristics and the average physical sizes of Koreans by age are shown in Table 2. The elderly subjects were on average 71.7 years of age, with the male subjects being 72.3 years of age and the female subjects being 71.0 years of age, as shown in Table 2. These subjects fell under the maximum of 4.6% (female weight) when compared with the average height and weight of the elderly above the age of 70 in Korea. These data imply that the measurements were gathered by targeting subjects close to the standard physical size. The average age of the control group was 26.1 years. Based on the standard physical size, the male subjects showed a +1.2% error in height and a −1.5% error in weight, while the female testers showed a +0.1% error in height and a −2.0% error in weight.

Figure 4. Ground reaction force plate.

Figure 5. External control unit.
Table 2. Standard physical size and subjects' average physical size.

| Distinction                             | Standard Physical Size | Physical Size of Subjects | Error (Error Rate) | Age |
|-----------------------------------------|------------------------|---------------------------|--------------------|-----|
| The elderly (healthy elderly (>70 years old, no disease)) |                         |                           |                    |     |
| male height                            | 164.2 ± 0.37           | 166.5 ± 5.31              | +1.4%              | 72.3|
| weight                                 | 63.96 ± 0.60           | 65.0 ± 7.02               | +1.6%              | (70+)|
| female height                          | 150.2 ± 0.38           | 154.2 ± 3.59              | +2.6%              | 71.0|
| weight                                 | 55.4 ± 0.48            | 58.1 ± 7.70               | +4.6%              | (70+)|
| Ordinary individuals (young adults (19–29 years old)) |                         |                           |                    |     |
| male height                            | 174.4 ± 0.34           | 176.5 ± 1.55              | +1.2%              | 26.1|
| weight                                 | 73.0 ± 0.76            | 71.9 ± 6.65               | −1.5%              | (19–29) |
| female height                          | 161.6 ± 0.35           | 161.7 ± 5.12              | +0.1%              | 26.1|
| weight                                 | 56.1 ± 0.61            | 55.0 ± 4.29               | −2.0%              | (19–29) |

4. Measurements and Results of the Characteristics of Normal Walking and Maximum Walking

4.1. Measurement of Walking Characteristics

The measurements of walking characteristics were conducted with the subjects wearing shorts and sleeveless tops in order to allow the exposure of their joints. Shoes were not worn, since errors such as balancing factors or disturbances in measuring the motion of ankle joints could occur depending on the function of the shoes worn. According to the Halen–Hayes marker set method (Figure 6) [17], the walking characteristics of all testers were measured by attaching a total of 29 markers. As the walking characteristics of the elderly could change [18,19] due to their higher sensitivity [20,21] to environmental changes than the non-elderly, the measurements were done after conducting 3–5 rounds of practice walking back and forth (Figure 7) in a manner that allowed adaptation to the clothes worn, the marker set and the measuring environment in order to minimize the errors attributable to such factors. For normal walking, the activity was carried out on a 6 m long walkway, and at this time, a comfortable environment was ensured to the best possible extent so that the usual walking characteristics could be obtained. For maximum walk, an instruction stating that a special situation (ending of traffic time during walking on a crosswalk, etc.) has occurred was given after completion of the normal walk. The testers were told to walk fast accordingly, and the walking characteristics were measured.

For both normal walking and maximum walking, only when the GRF Plate installed at the center of the pedestrian passage was stepped upon, was it measured as one time. Based on three steps of right foot and three steps of left foot, the walking characteristics of the elderly and ordinary individuals were measured.

The walking characteristics were categorized into four factors: gait factors, balance factors, bodily angle factors and muscle factors. Each factor was measured according to the 15 variables suggested by a previous study [13] which organized the variables related to walking based on results of relevant studies and expert advice. The results were exported as a chart and a picture via Othotrack version 5.0 (Motion Analysis Corporation, California, USA) as shown in Figure 8. The results were extracted by interpretation and comparative analysis. Statistical analysis and interpretation were performed using SPSS version 21.0 (IBM, New York, NY, USA), as shown in Table 1.
eristics were categorized into factors, bodily angle factors and muscle factors. Each factor was measured according to the sizes of these factors increased. This result implies that the increased walking speed was accompanied by increased amount of physical movement, resulting in difficulties in maintaining the balance.

4.2. Difference between the Normal Walking and Fast Walking of the Elderly

Table 3 compares the differences in gait factors of the elderly during a normal walk and a maximum walk. The walking speed increased by 38.29 cm/s, and all the gait factors excluding walk ratio increased. According to Table 4, which compares the balance factors, the sizes of these factors increased. This result implies that the increased walking speed was accompanied by increased amount of physical movement, resulting in difficulties in maintaining the balance.

**Figure 6.** Helen–Hayes marker.

**Figure 7.** The elderly tester.
For both normal walking and maximum walking, only when the GRF Plate installed at the center of the pedestrian passage was stepped upon, was it measured as one time. Based on three steps of right foot and three steps of left foot, the walking characteristics of the elderly and ordinary individuals were measured. The walking characteristics were categorized into four factors: gait factors, balance factors, bodily angle factors and muscle factors. Each factor was measured according to the 15 variables suggested by a previous study [13] which organized the variables related to walking based on results of relevant studies and expert advice. The results were exported as a chart and a picture via Othotrack version 5.0 (Motion Analysis Corporation, California, USA) as shown in Figure 8. The results were extracted by interpretation and comparative analysis. Statistical analysis and interpretation were performed using SPSS version 21.0 (IBM, New York, NY, USA), as shown in Table 1.

Table 3. Comparison of gait factors during the normal walking and fast walking of the elderly.

|                  | Walk Speed (cm/s) | Step Length (cm) | Stride Length (cm) | Step Width (cm) | Cadence (step/min) | Walk Ratio (cm/(steps/min)) |
|------------------|-------------------|------------------|--------------------|-----------------|---------------------|-----------------------------|
|                  | Ave. S.D.         | Ave. S.D.        | Ave. S.D.          | Ave. S.D.       | Ave. S.D.           | Ave. S.D.                   |
| Normal walk      | 121.00 14.53      | 60.27 8.62       | 117.65 12.24       | 10.93 2.96      | 123.13 9.43         | 0.49 0.09                   |
| Maximum walk     | 159.29 20.71      | 67.74 8.73       | 132.55 13.01       | 11.37 3.30      | 143.87 15.66        | 0.48 0.09                   |

Table 4. Comparison of balance factor during the normal walking and fast walking of the elderly.

|                        | Ground Reaction Force (N) | Center of Mass (m) | Pelvic Frontal Move (m) | Center of Pressure (m) |
|------------------------|--------------------------|--------------------|-------------------------|------------------------|
|                        | Ave. S.D.                | Ave. S.D.          | Ave. S.D.               | Ave. S.D.              |
| Normal walk            | 354.40 198.80            | 0.64 0.25          | 0.74 0.23               | 9.02 3.42              |
| Maximum walk           | 389.14 223.95            | 0.72 0.30          | 0.83 0.28               | 10.20 4.89             |

According to Table 5, which expresses the angle factors, the difference in the angle between the ankle and the sole related to nether extremities was not pronounced. However, a huge increase, especially in the movement of the right shoulder, which is the one mainly used, was shown. This finding implies that the movement of the upper body is greatly used to increase the walking speed. As is evident from Table 6, muscular factors, together with the increased walking speed, were shown to increase.
Table 5. Comparison of angle factor during the normal walking and fast walking of the elderly.

|                | Shoulder Angle (°) | Ankle Angle (°) | Foot Clearance (°) |
|----------------|--------------------|-----------------|--------------------|
|                | Right  | S.D.  | Left  | S.D.  | Right  | S.D.  | Left  | S.D.  | Right  | S.D.  | Left  | S.D.  |
| Normal walk    |        |       |       |       |        |       |       |       |        |       |       |       |
| Ave.           | 7.94   | 5.71  | 8.66  | 6.91  | 4.64   | 3.14  | 3.94  | 2.82  | 11.79  | 3.26  | 11.42 | 3.70  |
| Maximum walk   | 11.22  | 7.64  | 9.95  | 7.42  | 4.14   | 3.07  | 4.34  | 4.19  | 12.00  | 3.81  | 9.82  | 2.83  |

Table 6. Comparison of muscle factor during the normal walking and fast walking of the elderly.

|                | Knee (Nm) | Ankle Joint-Torque (Nm) |
|----------------|-----------|-------------------------|
|                | Extension | Flexion                 |
| Ave.           |           |                         |
| Normal walk    | 84.87     | 56.88                   |
| Maximum walk   | 114.59    | 67.20                   |

4.3. Results of the Measurement of Walking Characteristics of Ordinary Individuals

Tables 7–10 denote the results of analysis of gait factors, balance factors, angle factors and muscle factors of ordinary individuals during normal walking. During the maximum walking of ordinary individuals, a 48.42 cm/s increase was seen when compared to normal walking. Relatively, the increase rate of step width was not huge, but step length, stride length and cadence increased by >10% during maximum walking. Ordinary individuals increased their walking speed by about 26 steps (Cadence increase amount) per minute, while the step length increased by 10 cm.

Table 7. Comparison of gait factor during the normal walking and maximum walking of ordinary individuals.

|                | Walk Speed (cm/s) | Step Length (cm) | Stride Length (cm) | Step Width (cm) | Cadence (step/min) | Walk Ratio (cm/(steps/min)) |
|----------------|-------------------|------------------|--------------------|-----------------|--------------------|-----------------------------|
| Ave.           |                   | S.D.             | Ave.               | S.D.            | Ave.               | S.D.                        |
| Normal walk    | 133.34            | 16.27            | 66.16              | 8.38            | 133.82             | 12.96                       |
| Maximum walk   | 181.76            | 24.51            | 76.03              | 7.57            | 150.40             | 12.75                       |

Table 8. Comparison of balance factor during the normal walking and maximum walking of ordinary individuals.

|                | Ground Reaction Force (N) | Center of Mass (m) | Pelvic Frontal Move (m) | Center of Pressure (m) |
|----------------|---------------------------|--------------------|-------------------------|------------------------|
| Ave.           |                           | S.D.               | Ave.                    | S.D.                   | Ave.                  |
| Normal walk    | 182.94                    | 186.54             | 0.57                    | 0.29                   | 0.66                  |
| Maximum walk   | 227.01                    | 268.38             | 0.55                    | 0.34                   | 0.64                  |

Table 9. Comparison of angle factor during the normal walking and maximum walking of ordinary individuals.

|                | Shoulder Angle (°) | Ankle Angle (°) | Foot Clearance (°) |
|----------------|--------------------|-----------------|--------------------|
|                | Right  | S.D.  | Left  | S.D.  | Right  | S.D.  | Left  | S.D.  |
| Normal walk    | 7.85   | 6.35  | 8.83  | 6.47  | 4.60   | 2.25  | 4.49  | 2.80  |
| Maximum walk   | 7.74   | 5.61  | 8.46  | 6.35  | 4.60   | 3.31  | 4.90  | 4.34  |
Table 10. Comparison of muscle factor during the normal walking and maximum walking of ordinary individuals.

|                     | Knee (Nm)           | Ankle Joint-Torque (Nm) |
|---------------------|---------------------|-------------------------|
|                     | Extension | Flexion | Right  | S.D. | Ave. | S.D. | Right  | S.D. | Ave. | S.D. |
| Normal walk         |           |         |        |      | 62.53 | 47.82 | 35.09  | 23.51 | 102.82 | 79.29 | 91.79  | 51.38 |
| Maximum walk        |           |         |        |      | 92.75 | 89.50 | 57.03  | 68.45 | 91.12  | 101.04 | 94.58  | 73.34 |

In the case of ordinary individuals, the fluctuation observed in the balance factor during normal walking and maximum walking was not large. In order to improve walking speed, the GRF increased, but other body balance factors slightly increased or decreased. This is a result of the movement of the extremities of ordinary individuals increasing in order to enhance the walking speed, even though the movements of other parts did not experience any pronounced or minor changes. As shown in Table 9, change was barely seen in foot clearance between the ankle and the sole. As shown in the results in Table 10, although the thigh muscles were largely employed for increasing the walking speed during maximum walk, the use of the ankles did not show any significant change.

5. Discussion

The previous studies on the walking of the elderly are focused on individuals with a particular disease. It is known that the variability in the number of steps and stride time is huge in elderly with diseases [22,23] and that such individuals display the characteristics of slow walking [24,25] as the stride increases. Additionally, it has been suggested that as the age increases [26], walking disabilities worsen. On the other hand, there are not many gait studies conducted on the elderly without diseases that affect walking or who walk on their own without using any assisting device, although such individuals constitute the highest proportion. In particular, there are not many comparative studies on the walking characteristics of normal walking and maximum walking. This study may be considered valuable in this regard. Additionally, to extract the comparative results of walking characteristics attributed to aging, kinetic and kinematic measurements of ordinary individuals during normal walking and maximum walking were analyzed, and we make suggestions below.

The differences between the normal walking and maximum walking of ordinary individuals and the elderly in terms of the walking variables are as shown in Table 11. The increased rate of walking speed in the elderly is about 5% less than that in ordinary individuals, and the variables related to balance (Center of Mass (C.O.M.), pelvic frontal move, Center of Pressure (C.O.P.)) were measured to be about 12% greater. This result implies that in the same situation, walking speed increases minimally, but imbalance, which could directly lead to a fall accident, greatly occurs. This suggests that the characteristic of maximum walk of the elderly is increased movement. While the shoulder movement of ordinary individuals was minimally reduced, the right shoulder movement of the elderly, which is the main side for use, increased by 41.3%. Moreover, muscular strength of the ankle joint was shown to have increased by >10%. In case of the elderly, they try to forcefully increase the walking speed using a bigger movement, which leads to an excessive use of the body. Therefore, the center of the body is increasingly shaken and alterations such as those in the external environment and physical contact with others occur. Freezing of gait phenomenon follows and leads to a failure of maintaining the balance, thereby resulting in a fall accident. This problem is more pronounced in a maximum walk than in a normal walk. Thus, in a situation which requires maximum walking, external factors that caused sudden changes should be eliminated and a consistent maintenance of the environment until the completion of the maximum walking in the gait facility is required to prevent a fall accident.
To allow an easy recognition of the difference between walking characteristics of the elderly and ordinary individuals during normal walking and maximum walking, the variability rate was suggested in the bar chart as shown in Figures 9–12. As shown in Figure 9, gait factors exhibited similar patterns in both ordinary individuals and the elderly, while as shown in Figure 11, the biggest difference in balance factors was confirmed. It is a fact that everyone knows that balance factors must be strengthened to prevent and reduce fall accidents. Regardless of the causal relationship, according to the results of this study, the balance factors show a large difference between the general and the elderly, along with ankle joint-torque and shoulder angle. In other words, it means that elderly people with poor balance ability have weak ankle strength and the faster the upper body moves, the less. In order to overcome this, it is necessary to be able to maintain the angle of the ankle higher than the floor surface like the general public through the strengthening of the lower limb muscle strength. Strengthening the ankle may require strengthening the muscles of the calf and thigh, the entire lower extremity connected to it. Along with this, you need to strengthen the movement of your upper body to gain momentum by waving your arms, and to balance the left and right. If this type of management and exercise are carried out together, it is expected that the elderly will be able to strengthen their bodies in a form closer to the general public in the absence of a balance factor as shown in this study.

**Table 11.** Comparison of differences between normal walking and maximum walking.

|                        | Walk Speed (cm/s) | Step Length (cm) | Stride Length (cm) | Step Width (cm) | Cadence (step/min) | Walk Ratio (cm/(steps/min)) |
|------------------------|-------------------|------------------|---------------------|-----------------|--------------------|-----------------------------|
| Difference between maximum-normal walk | Ordinary individual | 48.42 | 9.88 | 16.59 | 0.75 | 26.00 | −0.03 |
|                        | The elderly | 38.29 | 7.47 | 14.90 | 0.45 | 20.74 | −0.02 |
| Increase rate | Ordinary individual | 36.3% | 14.9% | 12.4% | 7.1% | 21.9% | −4.6% |
|                        | The elderly | 31.6% | 12.4% | 12.7% | 4.1% | 16.8% | −3.2% |

|                        | Ground Reaction Force (N) | Center of Mass (m) | Pelvic Frontal Move (m) | Center of Pressure (m) | Right Shoulder Angle (°) | Left Shoulder Angle (°) |
|------------------------|--------------------------|-------------------|-------------------------|------------------------|------------------------|------------------------|
| Difference between maximum-normal walk | Ordinary individual | 44.07 | −0.02 | −0.02 | 0.18 | −0.11 | −0.37 |
|                        | The elderly | 34.73 | 0.08 | 0.09 | 1.18 | 3.28 | 1.29 |
| Increase rate | Ordinary individual | 24.1% | −3.1% | −2.9% | 1.8% | −1.4% | −4.2% |
|                        | The elderly | 9.8% | 12.1% | 11.7% | 13.1% | 41.3% | 14.8% |

|                        | Right Ankle Joint-Torque (Nm) | Left Ankle Joint-Torque (Nm) | Right Foot Clearance (°) | Left Foot Clearance (°) | Knee Extension (Nm) | Knee Flexion (Nm) |
|------------------------|-------------------------------|-------------------------------|-------------------------|------------------------|---------------------|-------------------|
| Difference between maximum-normal walk | Ordinary individual | −11.70 | 2.80 | −1.64 | 0.92 | 30.22 | 21.94 |
|                        | The elderly | −11.79 | 11.05 | 0.21 | −1.59 | 29.72 | 22.74 |
| Increase rate | Ordinary individual | −11.4% | 3.0% | −12.0% | 7.1% | 48.3% | 62.5% |
|                        | The elderly | −10.2% | 11.4% | 1.8% | −14.0% | 35.0% | 49.1% |

To allow an easy recognition of the difference between walking characteristics of the elderly and ordinary individuals during normal walking and maximum walking, the variability rate was suggested in the bar chart as shown in Figures 9–12. As shown in Figure 9, gait factors exhibited similar patterns in both ordinary individuals and the elderly, while as shown in Figure 11, the biggest difference in balance factors was confirmed. It is a fact that everyone knows that balance factors must be strengthened to prevent and reduce fall accidents. Regardless of the causal relationship, according to the results of this study, the balance factors show a large difference between the general and the elderly, along with ankle joint-torque and shoulder angle. In other words, it means that elderly people with poor balance ability have weak ankle strength and the faster the upper body moves, the less. In order to overcome this, it is necessary to be able to maintain the angle of the ankle higher than the floor surface like the general public through the strengthening of the lower limb muscle strength. Strengthening the ankle may require strengthening the muscles of the calf and thigh, the entire lower extremity connected to it. Along with this, you need to strengthen the movement of your upper body to gain momentum by waving your arms, and to balance the left and right. If this type of management and exercise are carried out together, it is expected that the elderly will be able to strengthen their bodies in a form closer to the general public in the absence of a balance factor as shown in this study.

![Figure 9. Gait factor.](image-url)
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Figure 9. Gait factor.

Figure 10. Muscle factor.

Figure 11. Balance factor.

Figure 12. Angle factor.

6. Results and Conclusions

As South Korea has become an aging society, a continuous growth in the socioeconomic activity of the elderly is expected [3]. In this case, the elderly naturally experienced a reduction in the walking ability when compared with the ordinary individuals, even when they maintain adequate physical health. When compared to the present scenario, an increased use of the general pedestrian passages by the elderly with reduced physical abilities is expected in the future.

The elderly have relatively higher chances of fall accidents than normal individuals due to their reduced physical and cognitive abilities, even when walking comfortably on flat land. According to the results of this study, the elderly are seen to face difficulties in maintaining their balance during maximum walking because of excessive physical movements. In other words, they face a high probability of experiencing a fall from an external stimulation or an unbalanced floor surface.

On a crosswalk, the reduced traffic light time often leads to maximum walking. Particularly, the elderly face difficulties completing the travel on a crosswalk within the traffic light time because of their slow walking speed, causing them to travel at their maximum pace. When this occurs, the risk of a fall increases further, owed to the reduced balance (increase in unnecessary physical movement). In order to reduce such accidents that may occur during walking, studies on facility standards based on walking characteristics
are required. This study is significant in this regard and suggests that the planning of facilities that may require the elderly to travel at maximum pace, including curbs on a crosswalk, should be executed by phase and reflect the walking characteristics of the elderly. However, before that, the improvement of the walking ability of the elderly should be given priority. Healthy lifestyles and efforts for them have been made in various ways in accordance with the recent global aging trend. According to the results of this study, there is no significant difference between the elderly and the general public in walking speed and knee utilization. However, it will be necessary to strengthen the movement of the upper body and ankle, which shows large differences. This allows one to maintain balance even when one has to support the whole body with one foot. Through this, it is expected that the elderly can lead safer and more active lives.

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**Institutional Review Board Statement:** This study is exempt from human testing (It corresponds to two items, such as a national commissioned study and a study using only simple contact measurement equipment or observation equipment that does not follow physical changes). In addition, the institution that conducted this study was a government-funded research institution, and it was conducted for the purpose of promoting the public welfare of the country. Therefore, it is not subject to ethical approval during research design and progress. In the process, sufficient explanations, guidance, and consent procedures were passed to the subject of measurement, and there was no activity in violation of ethical approval exemption, such as the research results were also used for designing facilities suitable for walking.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Data available on request due to restrictions eg privacy or ethical. The data presented in this study are available on request from the corresponding author. The data are not publicly available due to consent for use only in limited research.

**Conflicts of Interest:** The authors declare no conflict of interest.

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