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COMPARATIVE RESEARCH ON WALKING CHARACTERISTICS OF ORDINARY AND ELDERLY PEOPLE ON FLAT GROUND

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ABSTRACT

It is well known that establishing countermeasures against the aging global society is urgent. Therefore, countries in the world are preparing countermeasures, focusing on economic support policy for the elderly. However, there is still the lack of structural improvement to promote and encourage social activities of the elderly.

Therefore, this study focuses on the difficulties that the elderly may experience in using the walking facilities that are designed and built for ordinary people. Elderly people may experience inconvenience when they use walking facilities that are designed and built for physical fitness of ordinary people. To avoid such undesirable result, it is inevitable to conduct a study on walking characteristics of the elderly.

This study measures walking characteristics of ordinary and elderly people using Motion Analysis System. 16 variables from 4 factors (general, walking, balance and muscle) are measured. According to the findings, it is revealed that the average physical ability of elderly people is approximately 70% of that of ordinary people. It is expected that the findings can be used in designing and constructing elderly people friendly walking facilities in the future.

Key Words: Walking Characteristics, Ordinary, Elderly, Flat Ground, Comparison

Introduction

One of the most serious social issue that the global community, including Korea, faces on aging population. As shown in Figure 1, the world population is quickly aging. Particularly, Korea is the country with the quickest population aging. Population aging does not simply mean increase of the mean age. Rather, it has influence on reduction of socially and economically

active population and, therefore, weakening of national competitiveness. Although many countries in the world announce a variety of policy to delay the speed of population aging, there are little fundamental and practical solutions to stop this trend. As a result, they attempt to prepare and implement additional measures to promote social and economic activities of the elder.

As a part of such measures, the retirement age from social and economic activities may increase. However, as presented by Moon (2016), physical and cognitive ability of people are gradually decreased when they are getting old and, as a result, they have limitations in doing social and economic activities. Particularly, decrease of physical ability causes reduction of activity areas and time. One of contributors to such reduction is social infrastructure that is suitable for ordinary people. Generally, the design standards of pedestrian paths, stairs and ramps are based on physical conditions and capability of ordinary people. Therefore, elderly people experience difficulties in using such facilities because of their limitation on physical activities. In addition, there is a risk of falls when they use a facility that is not suitable for their physical conditions.

It is easily assumed that removing such risk factors can contribute to promotion of social and economic activities of the elder. Therefore, this study accurately measure how physical characteristics are different between ordinary and elderly people and which characteristic shows the biggest difference, using Motion Analysis System. Furthermore, we attempt to present a direction to improve walking facilities with the findings.

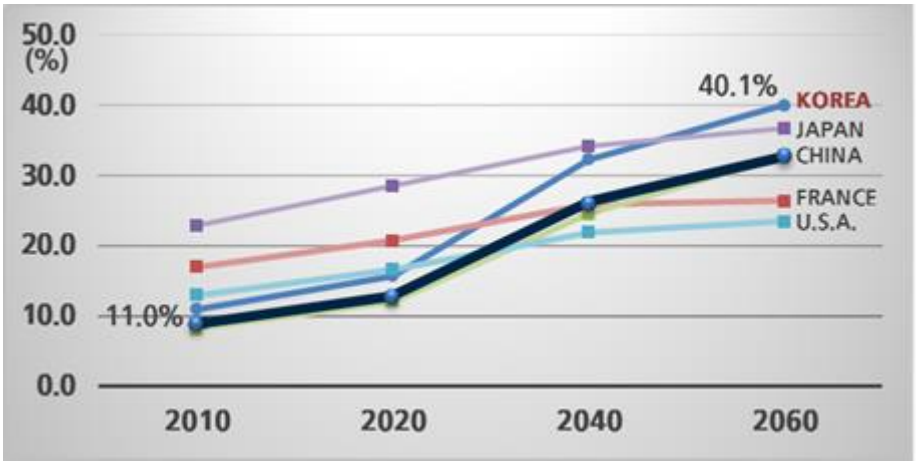

Figure 1 Increase Rate of Aged People

(Source: Statistics Korea, Supporting Expense and Aging Index, 2016. 4. 4)

Establishment of Principles to Measure Walking Characteristics

Evaluating walking from a certain point of view is difficult as walking is a comprehensive physical activity created by continuous movement. Accordingly, a design direction of walking facilities should be decided under comprehensive point of view. Therefore,

this study establishes the following principles to evaluate walking characteristics of a walking facility design for the elder.

①Continuity: There should be no disconnection at any point in circulation.
②Safety: Basic safety of elderly people in movement should be protected at any place.
③Convenience: A facility should help the elder maintain the most comfortable status, considering walking and motional characteristics.
④Universality: A facility should help the elder maintain equal relationship with ordinary people in terms of walking.

Variables are chosen from the balance factor, which decides the risk of fall (safety) in continuous walking, and the possibility of comfortable and continuos walking (continuity and convenience) to measure walking characteristics based on the principles above. To secure universality, a walking ability level of elderly people is investigated against walking characteristics of ordinary people.

Variables to measure walking characteristics of the elder are selected as followings. Walking factors are divided into four groups; General, Walking, Balance and Muscle. Total 16 variables have been decided to accommodate characteristics of each factor, with consultation of experts in Sport Biomechanics & Sport Information Science, based on the walking variables proposed by Perry (2010) and Roh(2015).

Table 1 Elderly Walking Variables of Each Factor

Factor	Variable	Definition
General	Angle of Shoulder(°)	Angle of Shoulder
	Angle of Ankle(°)	Angle of Ankle
Walking	Walking Speed (cm/sec)	the person's rate of travel by 1 second required 1 centimeter
	Walk Ratio(cm/(steps/min))	step length per cadence
	Cadence(steps/min)	number of steps in a given times(1 minutes)
	Step Length(cm)	distance between corresponding successive points of heel contact of the opposite feet
	Stride Length(cm)	sum of left and right step lengths
	Step Width(cm)	distance between right and left heel
	Foot Clearance(°)	foot's height during the swing phase
Balance	Center of Mass (m)	unique point at the center of a distribution of mass in body
	Pelvic Frontal Move	distance of the pelvic moves during walking

	(m)	
	Tilt(Pelvic)(°)	angle of the pelvic moves during walking
	Ground Reaction Force (N)	the force exerted by the ground on a body in contact
Muscles	Joint torque at ankle(Nm)	Joint torque at ankle
	Peak torque at knee-flexion(Nm)	the maximum strength of the leg when the knee bends
	Peak torque at knee-extension(Nm)	the maximum strength of the leg when the knee stretched out

Configuration of System

The motion capture system of Motion Analysis is used to analyze kinematic and kinetic variables that are required for analysis of walking characteristics of the elder. Equipment, hardware and software used for the analysis are listed in Table 2.

This study used 4 Raptor-E and 8 Eagle-4 infra-red cameras as imaging equipment for the analysis of walking movement. The shooting speed of the cameras was 120 frames per second. The shutter speed was 1/1000 second. The ground reaction force was measured by installing Force plate(Type 9260AA6, 600m×500mm×50mm) of KISTLER on the center of a pedestrian path. The acquisition rate was set to 1200Hz. The imaging devices and the ground reaction force were synchronized by electrical sync to synchronize their starting time. The coordinate data drawn from images were smoothed by a secondary Butterworth low pass filter. The frequency used was 6 Hz. The complete view of motion analysis system and applied systems are shown in Figure 2-6.

Table 2 Measuring Instruments and Analysis Programs

Instrument		**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

Figure 2 Motion analysis laboratory

Figure 3 Environment for analysis

Figure 4 Osprey4

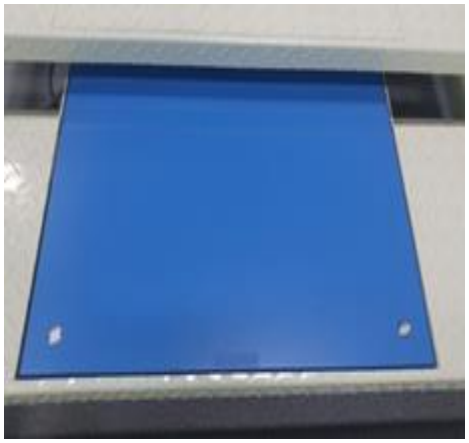

Figure 5 Ground Reaction Force Plate

Figure 6 External Control Unit

Measurement of Walking Characteristics

To find out walking characteristics of the elder, measurement results from 20 ordinary people and 173 elderly people (male: 65, female: 108) have been analyzed and presented. All elderly participants were over 65 years old, which is the guideline age of the elderly. Their standard height and weight were decided on the basis of the standard value of elderly people who were over 60 years old in Korea national health statistics. The mean age of the elderly participants was 76.4 years old, with the range from 66 to 89 years old. As the maximum error rate of height and weight was 5.4% (female weight), the measurement result obtained was similar with the standard of elderly Koreans. The mean of the participants and elderly Koreans are shown in Table 3.

Table 3 Error Rate of Participants

Classification		**Mean of Participants**	**Mean of Elderly Koreans**	**Error Rate**
Male	Height	166.0cm	166.5cm	- 0.3%
	Weight	63.9kg	67.1kg	- 5.0%
Female	Height	154.0cm	154.4cm	- 0.3%
	Weight	55.4kg	58.4 kg	- 5.4%

The participants' walking characteristics were measured by Motion analysis system when the total 194 participants including 20 ordinary people walked on a flat walking path including 10m×4m of the effective walking ground. The participants worn a sleeveless shirt or a short shirt to expose upper extremity. They did not wear shoes to accurately measure movement of an ankle. In addition, total 29 markers were attached the body of participants to obtain a coordinate of an ankle and form a segment axis in analyzing images according to the Helen-Hayes marker set method. The participants were asked to stand straight and a static photo was taken to calculate a body segment index. After that, markers attached to knees and inside ankles were removed. As a result, the test was conducted with the participants with 25 marker attached.

Measurement Results of Walking Characteristics

The measurement results of flat ground walking characteristics of both ordinary and elderly people are presented in Table 4. The variables generally used for balance factor analysis are Center of Pressure (hereinafter called as COP), Center of Mass (hereinafter called as, COM), Pelvic Frontal Move, Ground Reaction Force and Pelvic Tilt in this study. The variables mentioned above have multicollinearity by their properties. Therefore, it is necessary to select a certain variable to use according to the content of analysis. In general, COP among five variables mentioned above is used as a representative variable of the balance factor in kinetics. This study also uses COP in analyzing the balance factor, except for a certain analysis area.

As shown in the table, the analysis results of walking characteristics of the elder indicates that the elderly people has approximately 70% of walking ability of the control group (20's).

Table 4 Mean Measured Value of Characteristics for Flat Ground Walk and Comparison with Control Group

factor	**variable**		**Measured Value**		**%Nor**
			Target Group (66+)	**Control Group (20's)**	
General	Angle of Shoulder(°)	Right	8.04	8.97	89.6%
		Left	6.94	8.39	82.7%

	Angle of Ankle(°)	Right	13.23	8.52	155.3%
		Left	12.73	6.07	209.7%
Walking	Walk Ratio(cm/(steps/min))		0.45	0.65	69.2%
	Walking Speed (cm/sec)		91.86	137.30	66.9%
	Full body velocity		72.01	137.30	54.4%
	Cadence(steps/min)		109.75	109.50	100.2%
	Step Length(cm)		49.61	57.10	86.9%
	Stride Length(cm)		100.87	129.80	77.7%
	Step Width(cm)		11.78	12.00	98.2%
Balance	Center of Mass (m)		0.17	0.16	106.3%
	Pelvic Frontal Move (m)		0.35	0.28	125.0%
	Ground Reaction Force (N)		386.66	421.03	91.8%
	Tilt(Pelvic)(°)		3.66	8.24	44.4%
Muscles	Joint torque at ankle(Nm)	Right	125.88	145.6	86.5%
		Left	125.88	145.1	86.8%
	Peak torque at knee(Nm)	Flexion	167.59	166.30	100.8%
		Extension	51.74	61.30	84.4%

Conclusion

The comprehensive results drawn from comparison of walking characteristics between the ordinary and the elderly people are as follows:

- Movement of upper limb (shoulder) is slow while the angle of ankle is twice bigger than the control group in walking.
- People who have poor walking ability show increased small steps (increased Cadence) and low walking efficiency (bigger difference between walk speed and full body velocity).
- Because the elderly people have big movement of the center of body and gravity (COP and COM) and do not properly use sufficient force due to weak ground reaction force, their walk speed and walk ratio are low.
- The elderly people does not complete effective walking movement due to weak peak torque at knee-extension and, as a result, their step length and stride length value are small.

As shown in the findings, elderly people only have approximately 70% of walking ability of ordinary people due to reduction of physical ability caused by aging without illness or

injury. In other words, they does not use the body in an effective way and the center of gravity is significantly changed when they are walking. Such characteristics indicates that elderly people's risk of fall increases even if they use the walking facilities that can be used by ordinary people without difficulties. In addition, it also means that elderly people need more rest areas due to their physical limitations when they travel the same distance as ordinary people.

Entering the aging society is a social issue that should be discussed and solved by all community members, not just elderly people. In consideration of walking characteristics of elderly people, distribution of walking facilities that are systematic and suitable for the characteristics is urgent. Examples are distribution of stairs and ramps reflecting step width and available range of lower limb and provision of rest areas considering muscular force and endurance of elderly people. It is assumed that encouraging social and economic activities of the elder is only available in practice when such facilities are provided.

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