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Analysis of Gait Characteristics Changes in Normal Walking and Fast Walking Of the Elderly People

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Abstract: Korea has entered the Aged Society, which is expected to increase the social and economic activities of the elderly people. It is estimated that the walking ability of the elderly is about 70% of that of the general people. The decrease of the walking ability is expected to be a greater risk for the elderly in the fast walking situation than in the normal walking situation. In this study, we measured gait characteristics in normal walking and fast walking situations of elderly and general people and analyzed according to gait factors. The difference in the speed of normal walking and fast walking in the elderly was less than that of the general population, but the variables such as Center of Mass, Pelvic Frontal Move, and Center of Pressure corresponding to 'Balance Factors' were significantly increased. This means that it is difficult for elderly people to balance in the same situation compared to the general population, and the risk of falling can be increased. Therefore, in order to reduce the accidents that may occur during the walking in preparation for the walking activity of the elderly, which will be greatly increased in the future, it is necessary to prepare the standard of the walking related facilities based on the walking characteristics of the elderly.

Keywords: -Elderly, Gait Characteristics, Motion Analysis, Walking Ability,

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I. INTRODUCTION

South Korea has become the 'Aged Society' which means more than 14% of the population is over 65, in 2017, and is estimated to be 'Super-aged Society' in 2025. This means the pace of aging is the fastest in the world. It is predicted that the elderly in the Aged Society will have more economic activity than those in the past time(Choo. Et al., 2015). The increase in the economic activities of elderly people leads to an increase in the passage of elderly people, which means that more elderly people use various facilities than the existing ones.The elderly may feel uncomfortable to use the gait facilities equipped with the physical ability of the general person due to the deterioration of the physical ability and are exposed to the risk of accident while falling or falling. Unlike normal walking, which is the most relaxed state, they are exposed to the risk of accidents while in fast walking.

According to the study by Moon et al. (2016), as the age increases, there is a natural decrease in physical abilities and cognitive senses, which causes some limitations in the elderly's social and economic activities, especially the spatial and temporal utilization areas. Such reduction of the constraint and activity area is influenced by the walking facilities which are not suitable for the elderly person's physical and gait characteristics.In the study of Roh, et al. (2017), the walking characteristics of the elderly and the general were measured and analyzed using the Motion Analysis Systems. As a result, elderly people have a walking speed of 66.9% and a walking ability of 69.2% (walk ratio) compared to the general. This means that the elderly will have a 30% reduction in walking ability even with natural aging without any history of special symptoms or injuries, and there is a great risk of falling when using the walking facilities provided by the general.This difference in characteristics is expected to occur more frequently in the fast walking than in the normal walking. However, previous studies related to this have not been conducted.

Therefore, in this study, the body and gait characteristics of the elderly and the general were measured by the Motion Analysis Systems during the general walking and fast walking, and the change of gait characteristics was examined based on the basic statistical results. As a result, the gait characteristics of the elderly were more apparent than the general population. It is meaningful to provide basic data so that the facility considering the walking characteristics of the elderly will be provided in the future.

II. COMPOSITION OF WALKING CHARACTERISTICS ANALYSIS SYSTEMS

This The Walking Characteristics Analysis Systems based on the motion capture systems of Motion Analysis Corporation are used for analyzing kinematic and biomechanical variables of the elderly's walking

characteristics. Table no 1 shows the hardware equipments and software programs used to measure and analyze the variables.

In this study, 4 Raptor-E IR Cameras and 8 Eagle-4 IR Cameras to capture the subjects' movement. Shooting speed and shutter speed of each camera is set as 120 frames/sec, and 1/1000 sec. Ground Reaction Forces are measured by the force plate type 9260AA6(dimension: 600mm × 500mm × 50mm) of the KISTLER, installed center of gait way, and its acquisition rate is set as 1,200 ㎐. Imaging equipments and Ground Reaction Forece Plate are synchronized by electrically. Coordinate data extracted from IR image are calibrated using Second Order Low Pass Butterworth Filter with 6 ㎐ of cutoff frequency. Figure no 1 shows the motion analysis lab, and Figure no 2 ~ 4 show hardware equipments used.

Table no 1: Shows measuring equipments(H/W) and analyzing programs(S/W).

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 no 1: Shows View and Environment of Motion Analysis Lab.

Figure no 2: Shows Osprey4 (Camera System).

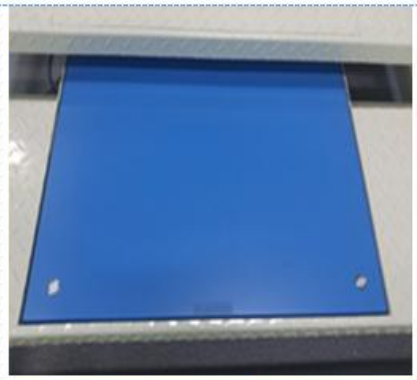

Figure no 3: Ground Reaction Force Plate.

Figure no 4: External Control Unit.

III. CHARACTERISTICS OF GAIT CHARACTERISTIC MEASUREMENT SUBJECTS

The gait characteristics of the elderly and the general public were measured during the normal walking and fast walking in the flat area.

Subject Size: 31 elderly (over 70 years old), 31 general (19 ~ 29 years old)

Subject Selection Method: The subjects were selected based on the Korean average body size survey data. All subjects meet the average body size in their age group.

Table no 2 shows the average body size of the subjects participating in gait characteristics and the average body size of each age group in Korea. The average age of the elderly subjects was 71.7 years, 72.3 years for men and 71.0 years for women as shown in Table 2. The subject was measured for subjects who were not older than the standard body size, within a maximum of 4.6% (female body weight) relative to the standard height and weight of the elderly people over 70 years of age in Korea.

The mean age of the control group was 26.1 years old and the subjects had the errors of the standard body size error of + 1.2% in the kidney, -1.5% in the body weight, and + 0.1% in the kidney and -2.0% in the body weight.

Table no 2: Shows measuring equipments(H/W) and analyzing programs(S/W).

Classification			Standard	Measured	Error	Avg. Subjects Age (Standard Age Group)
Elderly	Male	Height	164.2	166.5	+ 1.4%	72.3 (70+)
		Weight	63.96	65.0	+ 1.6%	
	Female	Height	150.2	154.2	+ 2.6%	71.0 (70+)
		Weight	55.4	58.1	+ 4.6%	
General	Male	Height	174.4	176.5	+ 1.2%	26.1 (19~29)
		Weight	73.0	71.9	- 1.5%	
	Female	Height	161.6	161.7	+ 0.1%	26.1 (19~29)
		Weight	56.1	55.0	- 2.0%	

IV. MEASUREMENT OF NORMAL WALKING AND FAST WALKING AND ITS RESULT

Walking Characteristics Measurement

Walking characteristics were measured by wearing sleeveless and shorts so that the body joints of the subject could be exposed. There is a possibility that errors such as balance factors may occur depending on the function of the shoes the subjects wear and the measurement of the movement of the ankle joint due to the shoes may be disturbed.

All subjects were attached to the body with a total of 29 markers according to the Halen-Hayes Marker Set method (shown in Figure no 5), and three to five rounds of walking were applied first to adjust to the worn costume and marker set actual measurement was performed.

In the normal gait measurement test, data were gathered as the subjects walked on the 6-m walkway, which provides the most comfortable environment so that the same walking characteristics as usual can be obtained. The fast gait measurement test proceeded immediately after the completion of the normal gait measurement test. It differs from the normal gait test that it generates a special situation such as an accident and measures the gait characteristics corresponding to the subject.

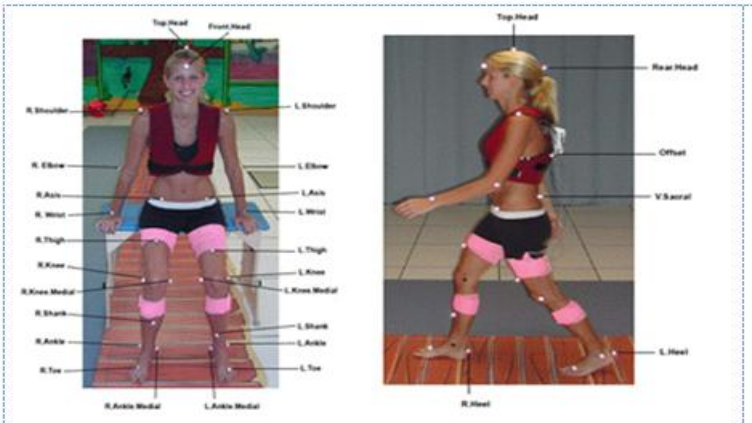

Figure no 5: Shows Helen Hayes marker (source: Motion Analysis User Guidebook).

Figure no 6: Shows the elderly subject.

Both the normal walking and the fast walking were measured as once when the Ground Reaction Force Plate installed on the center of the walkway was stepped on foot. Both right and left foot were measured three times for both the elderly and the general public.

Walking characteristics were classified into 'Gait Factors', 'Balance Factors', 'Angle factors', and 'Muscle Factors'. Each factor was measured and analyzed based on the 15 variables presented in Roh et al. (2017) which summarized the gait-related variables with reference to Perry's (2010) book.

Difference between Normal Walking and Fast Walking of the elderly

Table no 3 compares the mean difference of 'Gait Factors' among elderly people during normal walking and fast walking. Walking Speed increased by 38.29cm / s and Gait Factors except Walk Ratio increased. Table no 4 which compares 'Balance Factors' shows all 4 Balance Factors increase. This means that the movement of the body increases with the increase of the walking speed, which makes it difficult to maintain the balance.
According to Table no 5, which shows 'Angle Factors', the gap in angle between the ankle and the sole-floor surface related to the lower limb is not significant, but the movement of the right shoulder, especially the main arm, is significantly increased. This means that the upper body is used to increase the walking speed. In addition to the increase in walking speed, the 'Muscle Factors' were also increased as shown in Table no 6.

Table no 3: Compares the elderly's 'Gait Factors' between normal walking and fast walking.

	Walking Speed (cm/s)	Step Length (cm)	Stride Length (cm)	Step Width (cm)	Cadence (step/min)	Walk Ratio (cm/(steps/min))
Normal Walking	121.00	60.27	117.65	10.93	123.13	0.49
Fast Walking	159.29	67.74	132.55	11.37	143.87	0.48

Table no 4: Compares the elderly's 'Balance Factors' between normal walking and fast walking.

	Ground Reaction Force (N)	Center of Mass (m)	Pelvic Frontal Move (m)	Center of Pressure (m)
Normal Walking	354.40	0.64	0.74	9.02
Fast Walking	389.14	0.72	0.83	10.20

Table no 5: Compares the elderly's 'Angle Factors' between normal walking and fast walking.

	Shoulder Angle (°)		Ankle Angle (°)		Foot Clearance (°)	
	Right	Left	Right	Left	Right	Left
Normal Walking	7.94	8.66	4.64	3.94	11.79	11.42
Fast Walking	11.22	9.95	4.14	4.34	12.00	9.82

Table no 6: Compares the elderly's 'Muscle Factors' between normal walking and fast walking.

	Knee (Nm)		Ankle Joint-torque (Nm)	
	Extesion	flexion	Right	Left
Normal Walking	84.87	46.30	115.52	96.98
Fast Walking	114.59	69.04	127.31	108.02

Difference between Normal Walking and Fast Walking of the General

Table no 7 ~ 10 show the results of 'Gait Factors', 'Balance Factors', 'Angle Factors', and 'Muscle Factors' in normal walking and fast walking of the general. Walking speed increased by 48.42cm / s in fast walking. The increment of Step Width is relatively small, while the Step Length, Stride Length, and Cadence are increased by more than 10%. In the case of fast walking, the walking speed was increased by about 26 steps per minute (increase in cadence) with the step length increased by 10 cm.

The increase and decrease of 'Balance Factors' in normal walking and fast walking was not large. In order to improve the walking speed, the Ground Reaction Force was increased, but the other Balance Factors

were slightly increased or decreased. In general, the movement of the lower limb is larger and wider in order to increase the walking speed, while the movement of the other limb is less or less changed. As shown in Table 9, the foot clearance between the shoulder, ankle, and sole-foot surfaces also showed little change. As shown in Table 10, knee muscle strength was used to increase walking speed in fast walking, but the use of ankle was not significantly changed.

The results of analyzing the relative gait characteristics of elderly people and ordinary people at fast walking are presented in the next chapter.

Table no 7: Compares the general's 'Gait Factors' between normal walking and fast walking.

	Walking Speed (cm/s)	Step Length (cm)	Stride Length (cm)	Step Width (cm)	Cadence (step/min)	Walk Ratio (cm/(steps/min))
Normal Walking	133.34	66.16	133.82	10.45	118.92	0.56
Fast Walking	181.76	76.03	150.40	11.19	144.91	0.53

Table no 8: Compares the general's 'Balance Factors' between normal walking and fast walking.

	Ground Reaction Force (N)	Center of Mass (m)	Pelvic Frontal Move (m)	Center of Pressure (m)
Normal Walking	182.94	0.57	0.66	9.67
Fast Walking	227.01	0.55	0.64	9.85

Table no 9: Compares the general's 'Angle Factors' between normal walking and fast walking.

	Shoulder Angle (°)		Ankle Angle (°)		Foot Clearance (°)	
	Right	Left	Right	Left	Right	Left
Normal Walking	7.85	8.83	4.60	4.49	13.66	12.96
Fast Walking	7.74	8.46	4.60	4.90	12.02	13.88

Table no 10: Compares the general's 'Muscle Factors' between normal walking and fast walking.

	Knee (Nm)		Ankle Joint-torque (Nm)	
	Extesion	flexion	Right	Left
Normal Walking	62.53	35.09	102.82	91.79
Fast Walking	92.75	57.03	91.12	94.58

V. RESULT OF ANALYZING

Table no 11 shows the difference between fast walking and normal walking according to the walking variables of the elderly and the general public. In the elderly, the rate of increase in walking speed was about 5% less than that of the general population, while the balance related variables (Center of Mass, Pelvic Frontal move, Center of Pressure) were measured to be about 12%. It means that the elderly have the characteristic that the walking speed is lower than that of the general people in the same situation, but the fluctuation of the balance that can be directly connected to the fall accident is larger than the general.

The fast walking characteristic of the elderly is an increase in movement. The general showed that the movement of the shoulder was slightly reduced when fast walking compared to the normal walking, while the elderly had a 41.3% increase in the movement of the right shoulder, the main arm, in the same situation. The ankle joint strength also increased by more than 10%.

In order to make it easier to see the gait characteristics of the general and the elderly people during walking and fast walking, the change rates are shown in the bar charts as shown in Figures no7 ~ 10. As shown in Figure no 7, the Gait Factors are similar in both the general and the elderly, but the largest difference is found in the Balance Factor as shown in Figure no8.

Table no 11: Comparesdifferences between normal walking and fast walking by ages.

		Walk Speed (cm/s)	Step Length (cm)	Stride Length (cm)	Step Width (cm)	Cadence (step/min)	Walk Ratio (cm/ (steps/min))	Ground Reaction Force(N)	Center of Mass(m)	Pelvic Frontal Move(m)	Center of Pressure (m)
Differences in Fast Walking-Normal Walking	General	48.42	9.88	16.59	0.75	26.00	-0.03	44.07	-0.02	-0.02	0.18
	Elderly	38.29	7.47	14.90	0.45	20.74	-0.02	34.73	0.08	0.09	1.18
Increase Rate	General	36.3%	14.9%	12.4%	7.1%	21.9%	-4.6%	24.1%	-3.1%	-2.9%	1.8%
	Elderly	31.6%	12.4%	12.7%	4.1%	16.8%	-3.2%	9.8%	12.1%	11.7%	13.1%
		Right Shoulder Angle(°)	Left Shoulder Angle(°)	Right Ankle Joint-torque (Nm)	Left Ankle Joint-torque (Nm)	Right foot clearance (°)	Left foot clearance (°)	knee extesion (Nm)	knee flexion (Nm)	Right Ankle Joint-torque (Nm)	Left Ankle Joint-torque (Nm)
Differences in Fast Walking-Normal Walking	General	-0.11	-0.37	-11.70	2.80	-1.64	0.92	30.22	21.94	-11.70	2.80
	Elderly	3.28	1.29	11.79	11.05	0.21	-1.59	29.72	22.74	11.79	11.05
Increase Rate	General	-1.4%	-4.2%	-11.4%	3.0%	-12.0%	7.1%	48.3%	62.5%	-11.4%	3.0%
	Elderly	41.3%	14.8%	10.2%	11.4%	1.8%	-14.0%	35.0%	49.1%	10.2%	11.4%

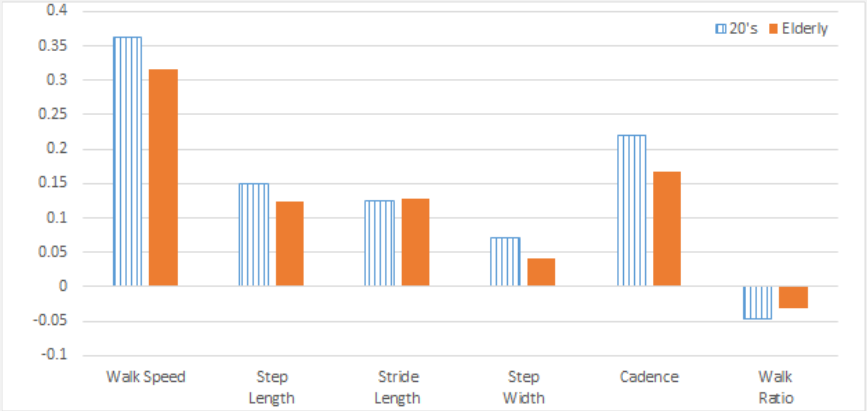

Figure no 7: Shows change rate of 'Gait Factors' by ages.

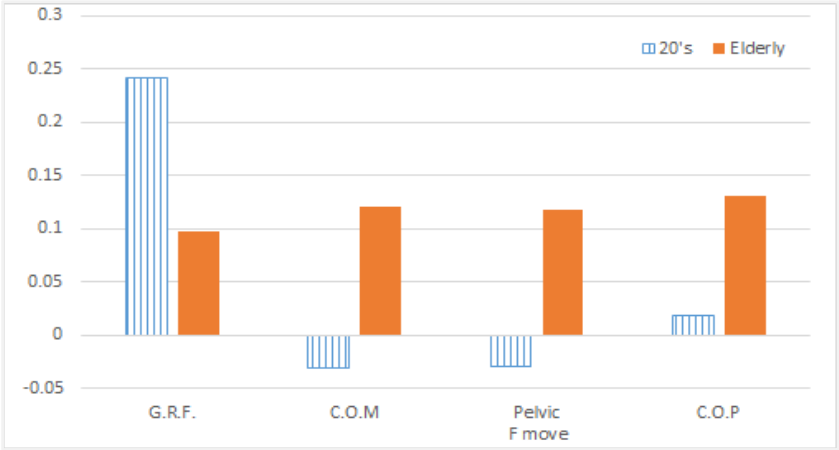

Figure no 8: Shows change rate of 'Balace Factors' by ages.

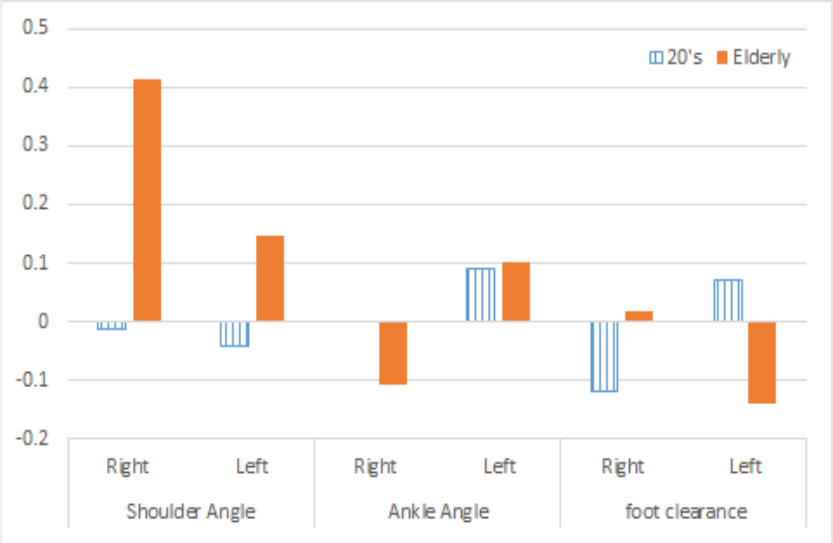

Figure no 9: Shows change rate of 'Angle Factors' by ages.

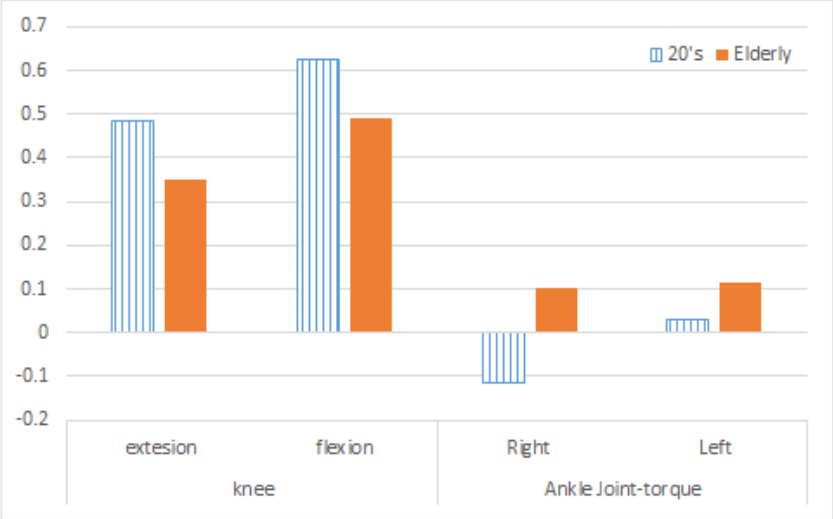

Figure no 10: Shows change rate of 'Muscle Factors' by ages.

VI. CONCLUSION

With the entry of the Aged Society, South Korea is expected to continuously increase the social and economic activities of the elderly (Choo et al. (2015)). No matter how well an elderly person maintains health, their physical and walking ability naturally decrease compared to the general (Roh et al. (2017)). Taken together, this means that the use of the walking path of elderly people with decreased physical abilities is further increased.

Elderly people are exposed to the risk of falls due to the decrease of balance ability even in normal walking compared to the general. According to the results of this study, the elderly have an increased Balance Factors due to excessive body movements during fast walking. This means that when an external stimulus occurs while the elderly are fast-walking, they are likely to lose their balance and fall.

It is necessary to change the facilities of the walkways to encourage the social and economic activities of the elderly. In Korea, there are some cases, the facility standard for the elderly is the same as that for the general public. Since elderly people may be sensitive to environmental changes unlike ordinary people, improvement of facilities should be based on user's walking characteristics. As the signal time decreases during the use of the crosswalk, it often happens to move to fast walking. In particular, the elderly have difficulty in completely passing the pedestrian crossings within the signal time due to low walking speed, and thus move to fast walking. The risk of falls is further increased by the reduction of balance (increase of unnecessary body movements) during fast walking. In order to reduce the risk of such accidents during walking, it is necessary to study the facility based on gait characteristics. This study contributes to this aspect and it is necessary to reflect

the gait characteristics of the elderly when planning and designing the walking facilities where the elderly are expected to use fast walking.

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