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ANALYSIS OF CORRELATION BETWEEN THE HEIGHT OF STAIRWAY HANDRAIL, BODY SIZE AND WALKING PATTERN OF THE AGED

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ABSTRACT

In line with aging population on the rise globally, economically active population is increasingly growing and trip frequency of the aged is predicted to increase accordingly. Increase in trip frequency of the aged means the increase in use of walking environment by the aged and thus the aged uses more various walking facilities. As a result of reviewing the relevant documents, the aged feels more physical difficulties while walking up or down the stairs. Particularly on stairs, it's more difficult to make the physical balance of the body because of different movement from the even ground and given the walking pattern of the aged, falling risk is very high. Stair handrail is the device that prevents falling accident.

Stair handrail used to be installed at a certain height to prevent the people from falling out of the stairs and in case of the mobility handicapped, it's recommended to install at 85cm, which however lacks the objective base.

In this study, the stair handrail which the aged feel comfortable was investigated by height, qualitatively, and the correlation between the body height and walking pattern of the aged was analyzed based on data measured. According to the investigation, the aged preferred a certain height (87cm) irrespective of the body height which is different from the expectation that handrail height would have close correlation with the body size such as height.

Such data is expected to make commitment to promoting the economic activities of many elderly people in a way of preventing the fall accident as well as ensuring safe and comfortable walking.

Key Words: height of stairway handrail, body size, walking pattern, elderly, correlation analysis

Introduction

Walking on stairs is different from walking on even ground in walking pattern. Stair walking pattern is divided into supporting stance and holding stance and supporting foot is repeated alternately and is the particular walking that has the moment when both foot stands on the ground together. And it's a complex and dangerous motion requiring a series of action to maintain the physical balance of the body for stable movement while walking up or down the stairs, hence, stair handrail plays an important role for safe and stable walking on stairs.

Previous studies on kinematic characteristics of stair walking are summarized as follows. Kim, et al.(2006) analyzed that the people tends to lean forward when walking up the stairs while maintaining their pelvis lower. At this time, their ankle angle tends to bend further. On the other hand, hip joint angle, ankle valgus and outside rotation were positioned higher while walking down the stairs.

Then the change to pelvic tilt leads the gravity center of the body forward by tilting the upper body forward and upward while walking up the stairs. At the same time, waking is continued by tilting the pelvis forward. When walking down the stairs, gravity center of the body is maintained on base or backward so as to prevent the upper body from leaning forward, thereby minimizing the motion of upper body.

Stair walking with such motion, according to McFadyen and Winter(1988), lifting is significant together with translation, causing the difficulties in maintaining the balance, which results in increasing fall accident risk than walking on even ground. Viewing such behavior, the risk of falling out of the stairs for the aged is higher than other age groups. The aged has more difficulties with the movement of balance even on flat floor which is attributable to lack of force while lifting the body.

Stair handrail is the device to prevent fall accident that may be caused by such walking pattern. When the stair handrail is not installed at proper height, it may cause the fall accident because of interrupting the smooth weight shift. This study is intended to qualitatively evaluate the comfort by height of handrail for the aged and correlation between the measured data and walking ability and body size. The outcome is expected to be useful in determining the proper height of stair handrail to protect the aged from falling out of the stairs.

Measurement of walking pattern

Motion Analysis System in Table 1 and Figure 1 and 2 was used to measure the walking pattern of the aged on even ground. In this study, 4ea Raptor-E and 8ea Eagle-4 infrared cameras were used to analyze the walking pattern of the aged, Shooting speed was set at 120frames/sec.

Walk Speed, Step Length, Stride Length and Step Width were measured and Cadence and Walk Ratio were estimated using the measured data. Besides, Height, Weight, Foot Length and Foot Width of the subject were also measured. Then the analysis of correlation between handrail level, body size and walking pattern was conducted after marking the gender.

Table 1 Instrument and analysis program

Instrument		Model	Manufacture country
Hardware	CCD Camera	Raptor-E and Eagle-4	USA
	VCR	Go-pro	Korea
Software	Cortex	ver. 6.0	USA
	Othotrack	ver. 5.0	USA
	SPSS	ver. 21.0	USA

Figure 1 Motion analysis lab.

Figure 2 Walking analysis environment

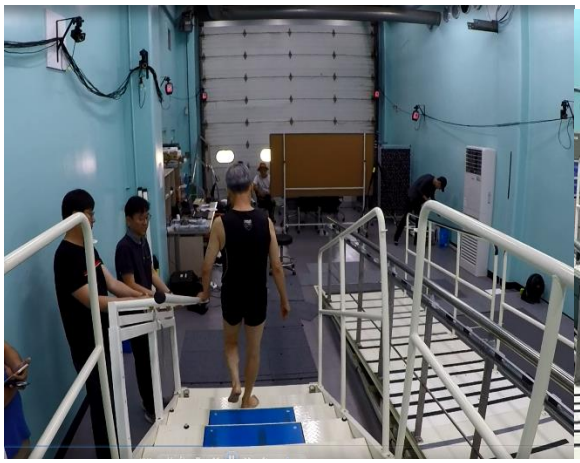
Measurement of preferred handrail level

According to Roh(2017), the step height ensuring stable walk by the aged was less than 15cm. Thus the step height was set at 15cm, the maximum height, and handrail level was set adjustable so as to quantitatively measure the height which the aged feel comfortable while walking up and down the stairs.

Handrail height was set at 5 levels, from 0cm to 90cm, 100cm, 110cm and 120cm. Such height was determined in consideration of the average height of the men 166.5cm and 154.4cm of the women and the mean value 80cm was considered the minimum height. Maximum height was set at 120cm which is the height of handrail installed to prevent fall accident. The height was adjusted by increasing it from the minimum height by 10cm considering the use comfortably.

The stair of which height is adjustable as seen in Fig 3 was used and the stair has 5 steps. Walking up and down the stairs without handrail was performed 5 times(Fig 4 and 5) to adapt to the instrument prior to start measuring.

Figure 3 Stair instrument



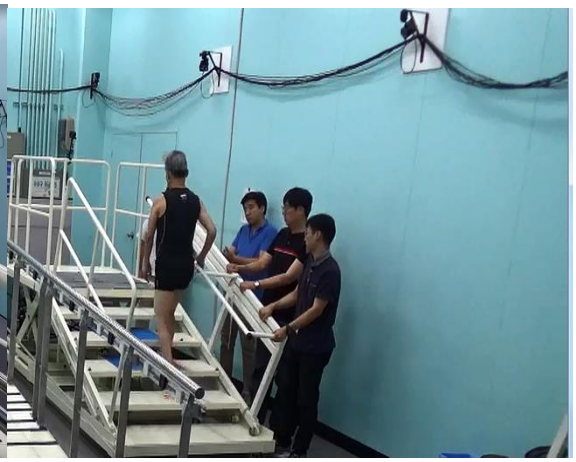


Figure 4 Walking down Figure 5 Walking up

The subject

The subject was selected to determine the optimal height of stair handrail for the aged. The subject was selected among those who have a certain walking ability to prevent the fall accident, avoiding those whose sense of balance are deteriorated. Based on such principle, 29 subjects were selected and the comfort level by handrail height was measured and the body size of the subject is as Table 2 in which the difference in body size between the subject and the standard Korean was also described. The mean value of the aged includes the height and weight of the person aged 60 or older which was presented by the Ministry of Health and Welfare in National Health Statistics, Oct 2016. Maximum error range between the subject and the aged in statistics is within 5.4%. The error in height is 0.3% which is considered similar with the standard value of the aged.

Table 2 Standard contrast error

Sort		Average(Measurement)	Average(Standard)	Error rate
Male (14 persons)	Height	166.0cm	166.5cm	- 0.3%
	Weight	63.9kg	67.1kg	- 5.0%
Female (15 persons)	Height	154.0cm	154.4cm	- 0.3%
	Weight	55.4kg	58.4 kg	- 5.4%

Analysis of descriptive statistics

Descriptive statistics on analysis of walking pattern of the aged and preferred height is as Table 3. Preferred average stair handrail height was 87.24cm and the standard deviation was 5.91cm. Walking pace was 120cm/s which is similar with average pace of ordinary person, which means the walking pace of the subject on even ground was similar with other ordinary person, who are able to do social and economic activities.

Table 3 Analysis of descriptive statistics

Sort	Definition	average	S.D.	N
handle height	Height of the stair handrail	87.24	5.91	29
walk speed	the person's rate of travel by 1 second required 1 centimeter (cm/sec)	120.12	14.58	29
step length	distance between corresponding successive points of heel contact of the opposite feet (cm)	59.82	8.73	29
stride length	sum of left and right step lengths (cm)	116.75	12.12	29
step width	distance between right and left heel (cm)	10.99	3.05	29
cadence	number of steps in a given times(1 minutes) (steps/min)	123.22	9.75	29
walk ratio	step length per cadence (cm/(steps/min))	.49	.09	29
gender	Male(1) or Female(2)	1.52	.51	29
height	-	160.41	8.29	29
weight	-	62.18	9.49	29
foot length	-	238.97	13.98	29
foot width	-	91.48	5.49	29

Mean body height which is considered has direct relationship with handrail height was 160.4cm and Walk Ratio indicating the walking ability comprehensively was 0.49 which corresponds to 75% of 0.65, the mean value of other ordinary person presented by Roh(2017).

Analysis of correlations

Analysis result of the correlations between the stair handrail height, walking pattern of the aged and body size is as Table 4. Statistics Tool used was SPSS 18.0 and bivariate correlation coefficient analysis was conducted. Correlation coefficient applied was Pearson Correlation Coefficient (P.C.C.) and significance probability was estimated for both sides. When significance probability is $p<0.05$, it's considered to have correlations statistically.

Table 4 Analysis of correlation between handrail height, walking pattern and body size

handrail height			**walk pace**			**step length**		
P.C.C	SP (both)	N	P.C.C	SP (both)	N	P.C.C	SP (both)	N
1	-	29	-0.03	0.876	29	0.261	0.171	29
stride length			**step width**			**cadence**		
P.C.C	SP (both)	N	P.C.C	SP (both)	N	P.C.C	SP (both)	N
0.218	0.256	29	-0.207	0.281	29	-.369*	0.049	29
walk ratio			**gender**			**height**		
P.C.C	SP (both)	N	P.C.C	SP (both)	N	P.C.C	SP (both)	N
0.329	0.081	29	-0.102	0.597	29	0.169	0.381	29
weight			**foot length**			**foot width**		
P.C.C	SP (both)	N	P.C.C	SP (both)	N	P.C.C	SP (both)	N
-0.105	0.586	29	0.051	0.794	29	0.152	0.43	29

According to analysis, 1 variable indicating the significance probability has correlations statistically was Cadence($p=0.049$) Body height which is considered to have close relations with using the handrail while walking on stairs has the significance probability $p=0.381$ indicating no correlation exists. Significance probability of walking pace was very high ($p=0.876$) indicating walking pace and handrail height have very sporadic distribution.

The result of confirming it in scatter plot is as Figure 6~8. Each Fig is the scatter plot showing the relations between handrail height, walking pace, cadence and the height, together with a linear trend line. Trend analysis result same as correlation analysis result was identified. Though the body height had the correlation slightly but not statistically significant. Walking pace appeared to have had no correlations with handrail height.

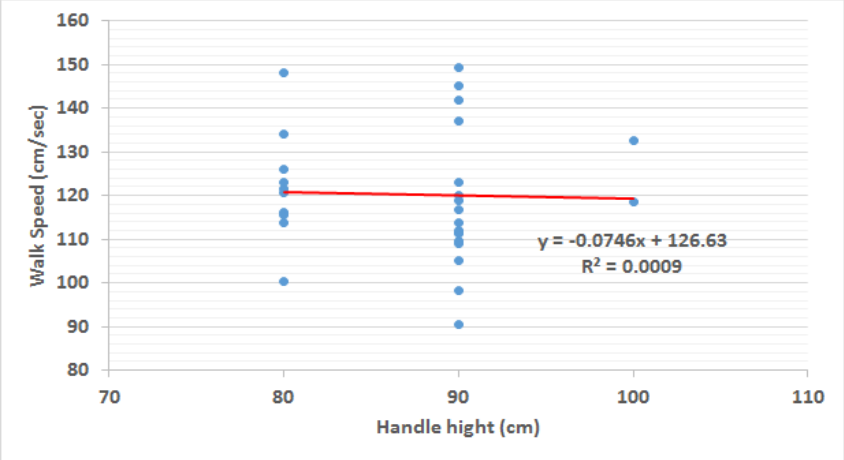


Figure 6 Scatter plot on walking pace-stair handrail height

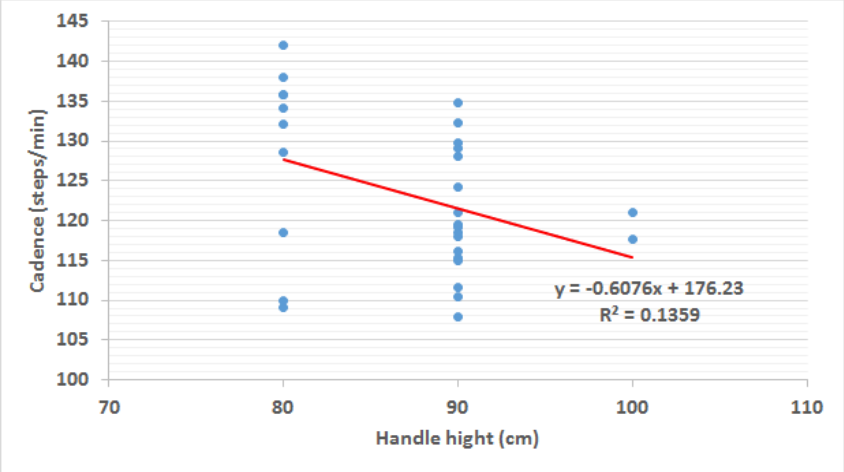


Figure 7 Scatter plot on Cadence-stair handrail height

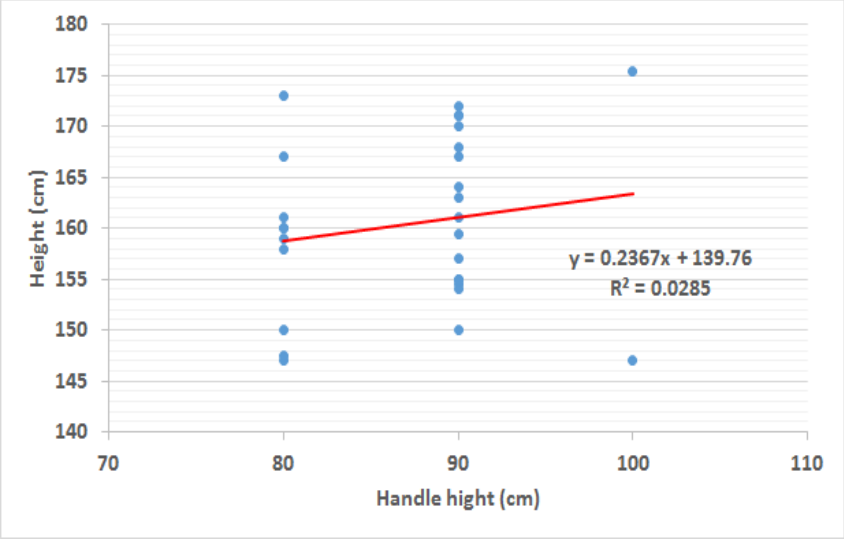


Figure 8 Scatter plot on body height-stair handrail height

Acknowledgments

Entering the ageing society, it's necessary to prepare for increasing social activities and using walking environment by the aged. But social environment has yet to be ready to accommodate the aged. Particularly, walking environment has been designed and provided to fit the physical condition of the ordinary person only. Thus, the efforts to provide the aged with the facilities which are suitable to the body size and walking pattern of the aged are to start.

This study started from such a point of view and basic analysis with regard to the stairs which the aged has difficulties in using was conducted. Consequently, body size of the aged had no correlation with the stair handrail height, which is contrary to the prediction. That is, the aged with average body size had no inconvenience with 87cm-height handrail, irrespective of the body height. Such result seems to be different from the ordinary person.

Cadence had the relation partially with the stair handrail but the standard deviation of Cadence distribution of the aged is 9.7 which is less than 8% comparing to the mean value and thus on assumption of using by the aged, no inconvenience would be expected with the handrail at preferred height.

It's necessary to develop the design guideline for the stairs including step height, width and handrail material and provide the facilities so as to prevent fall accident by the aged as well as ensure the aged to enjoy safer and comfortable walk, thereby making commitment to encourage them to do various economic activities.

Acknowledgments

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