

Study on the Relation between Age and Evacuation in Case of Undergroud Evacuation

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Abstract

Many codes and standards regarding fire safety are designed and established based on healthy adults in general. Human represent many different properties in various aspects depending upon age. The study tried to identify the relation between age and evacuation depending on visibility. Correlation analysis and linear regression analysis were conducted to identify the correlation between the subject's age and evacuation speed. As the visual impairment became stronger, the correlation between age and speed became smaller.

Keywords: Evacuation, Fire drill, Visibility, Age, Fire safety

1 Introduction

Many codes and standards regarding fire safety are designed and established based on healthy adults in general. Occupants can experience evacuation safety in a building mostly used by children or senior who have poor physical ability or decision ability. As of 2012, children below 14 old age accounted for 15.1% while those aged 65 or older 11.8% of the entire population in Korea and the percentage of the elderly is expected to increase. Human represent many different properties in various aspects depending upon age. Particularly, the exercise ability is reached a peak in twenties and then, gradually declined. This decline is getting more drastic after fifties. In sixties, the exercise ability is about 70~80% of adults in twenties. Differences in exercise ability are normally reflected into evacuation behaviors hence representing various evacuating characteristics. It is critical to have accurate data regarding behavioral characteristics of evacuation according to age for Performance Based Design as well as reliable evacuation simulation result.

The study aimed to identify correlation between age and evacuation. Evacuation experiments were performed to analyze evacuation time and speed according to age. Visibility was reduced as an environmental constraint over evacuation. It was also analyzed how the evacuation changes depending on age as well as the visibility. Quantitative data on correlation between age and evacuation were discussed through the analysis in this study.

2 Experiment summary

The evacuation experiments were conducted in subway stations which have four underground stories, located in Daegu, South Korea. Subjects of the evacuation experiment started from the center of subway platforms in the fourth underground story and evacuated to the exit on the ground level. Subjects evacuated one by one at regular intervals and then a questionnaire about the experiment was surveyed after the completion of evacuation. Evacuation routes, time, behavioral factors were recorded by a recorder who was following the subject throughout the evacuating experiments.

Three evacuation experiments with three different visibility conditions were conducted. The three visibility conditions applied to the experiments are summarized in the table 1. In the condition of Test 1, all indoor lights and equipment were normally operational while all indoor lights were turned off except for exit signs and several billboards in Test 2 and 3. In particular, the Test 3 in impaired visibility condition simulated the evacuation drill in the event of fire with smoke. Subjects of Test 3 have the reduced visibility as well as visual impairment due to the smoke in hindrance condition as shown Fig 2. In order to make condition, meaning impaired visibility, the subjects put on the opaque eye-patch which allows transmission of about 27% visible light in average. With the opaque eye-patch, the visibility of subject becomes approximately 5~10 meters which can be converted to

0.13~0.26 m⁻¹ as the smoke density value. Under the smoke density of 0.13~0.26 m⁻¹, the fire alarms in building may be activated and occupants who are unfamiliar with building path take difficulties for the evacuation.

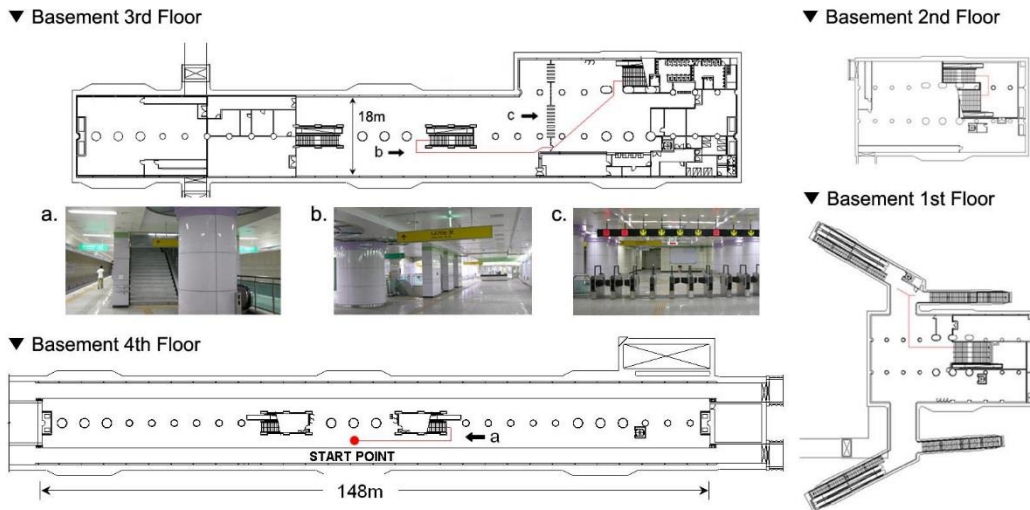


Fig. 1. Subway station. The fourth underground story was being used for subway platforms while the third underground story was being used for tickets and waiting rooms.

Table. 1. Experiment scenario and condition

Index	Visibility condition	Indoor lights	Opaque eye-patch
Test 1	normality	work	-
Test 2	light-off	-	-
Test 3	hindrance by smoke	-	put on



Fig. 2. Visibility before (left) and after (right) putting on the eye-patch

In this study, subjects were classified into three age groups based upon the human life cycle. The subjects below 20 were Group A, those between 20 and 50 were Group B and those aged 50 and older were Group C and all the subjects were recruited from ordinary citizens. A total of 103 subjects with a wide range of age were involved in experiment. As shown Fig 3, the average age and height of subjects were 27.7 years old and 167.7cm, respectively. The youngest subject was 9 years old while the oldest was 67 years old.

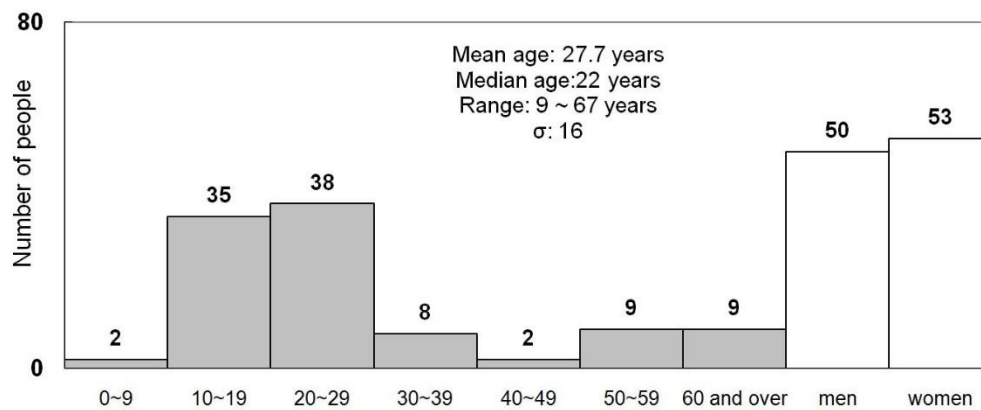


Fig. 3. Personal information of subjects

3 Evacuation experiment result

There were significant differences in evacuation time per each test as shown in the Fig 4. In the test 1, the mean evacuation time was 112.1 seconds which is the shortest while it was found to be 425.5 seconds in the test 3. Test 3 recorded a greater deviation of evacuation completion time than Test 1 and 2. The evacuation time of the test 3 exceed over 1 minute of evacuation time which is allowed by NFPA 130 code in the USA.

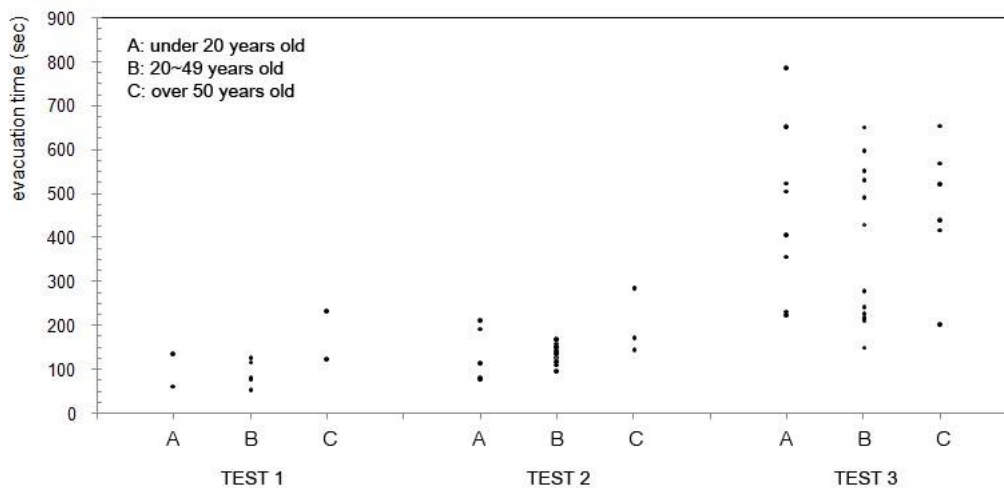


Fig. 4. Distribution of evacuation time

With the condition of impaired visibility, due to power failure and smoke, the evacuation time was significantly increased differently according to the age as well as evacuation space. As the table 2 shows, Group B in the Test 1, Group A in the Test 2 and Group B in the Test 3 took the shortest time to evacuate while Group C, the oldest, took the longest time for evacuation at all tests. At all age groups, Test 1 with the best visibility recorded the shortest time to evacuate and Test 3 with the

worst visibility showed the opposite. In the meantime, Group A, the youngest, showed the greatest difference of evacuation time under the condition of different visibility. In the test 2, without indoor lights, Group A and Group B showed the similar evacuation time. With impaired visibility due to smoke, Group A and Group C were similar in time took for evacuation in the test 3. On the other hand, a slightly different pattern was found in evacuation time depending upon the evacuation space. In test 2&3, Group A showed the shortest evacuation time in staircase whilst it was longest in the Group C.

Table 2. Evacuation time depending on age classification

Exp. index	Age classification			
	A (0-19)	B (20-49)	C (50 and over)	All age
Test 1	99.2	90.9	178.1	112.1
Test 2	134.6	138.4	221.5	154.1
Test 3	460.3	381.3	467.2	425.5

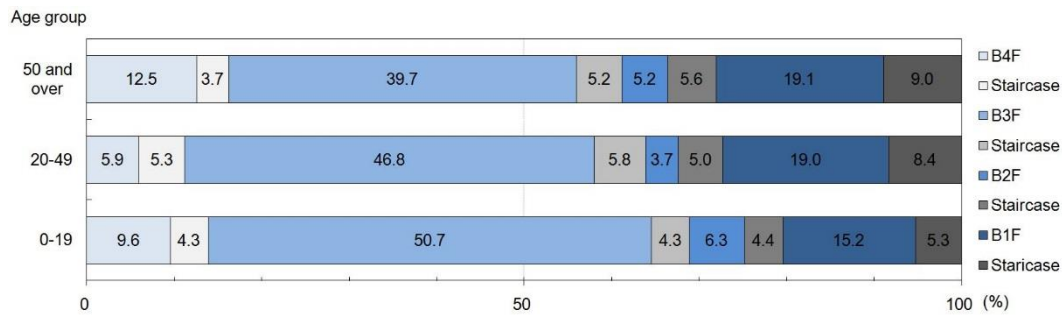


Fig. 5. Evacuation time ratio in Test 3

4 Relation analysis and discuss

The evacuation speed which is calculated using the evacuation time and moving distance was shown in the Fig 5. Although the difference was smaller than the evacuation time, there was a clear difference in the evacuation speed. As the figure 6 shows, the evacuation became slower when the visibility grew worse in general. It was 2.33m/s at Test 1, 1.70m/s at Test 2 and 0.89m/s at Test 3 on average. However, Group C recorded the fastest evacuation at Test 2, which had the medium visibility constraint, without following the pattern. Though Group C, the oldest, was the slowest to evacuate typically, their evacuation time depending on constraint conditions was the least different.

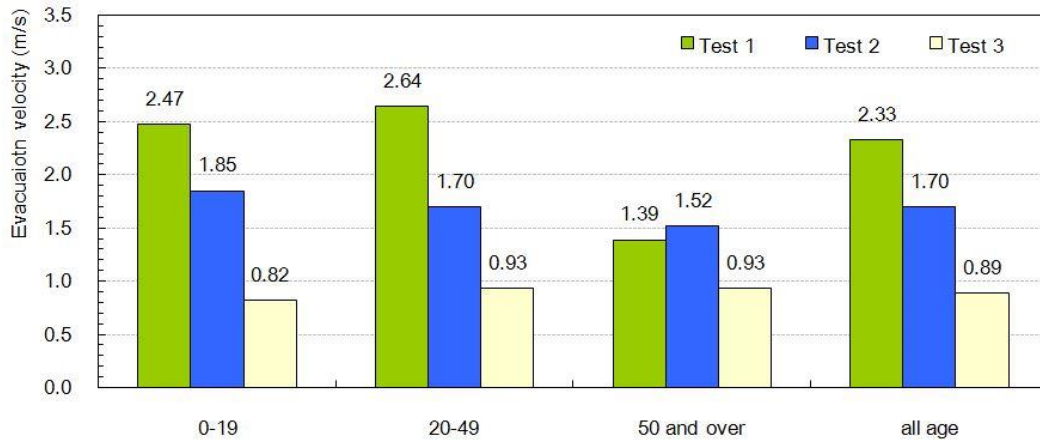


Fig. 6. Evacuation speed comparison

If the evacuation speed of Test 1 that has no visual hindrance is assumed default value as "1", the speed of Test 2 slows to 0.73. Test 3 speed also slows to 0.38, less than half Test 1. Such difference also varied depending on the age group shown in Table 3.

Table 3. Relative comparison of the evacuation speed

	Test2/Test1	Test3/Test2	Test3/Test1
0-19	0.75	0.44	0.33
20-49	0.64	0.55	0.35
50 and over	1.10	0.61	0.67
All age	0.73	0.52	0.38

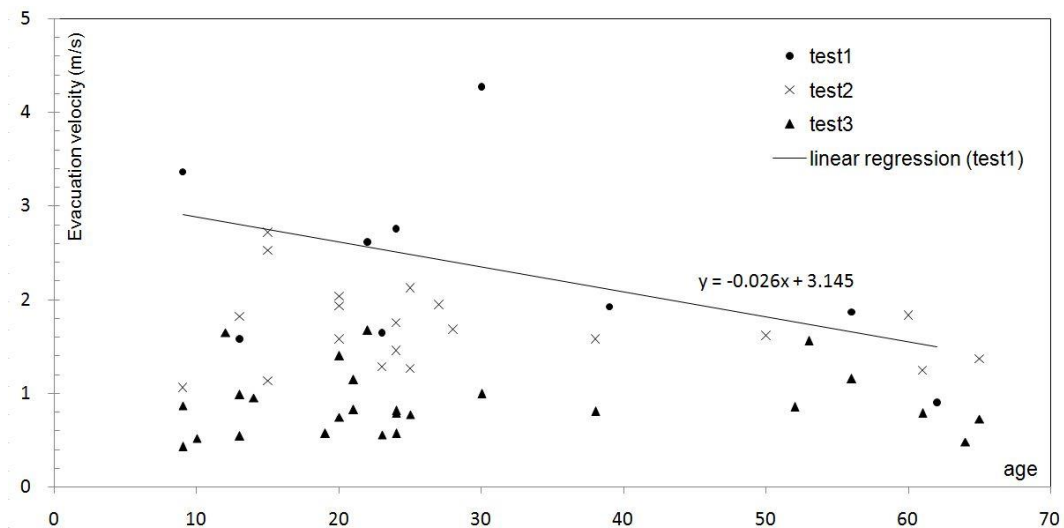


Fig. 7. Linear regression analysis between age and evacuation speed

Correlation analysis and linear regression analysis were conducted to identify the correlation between the subject's age and evacuation speed. Test 1 without vi-

sibility constraint recorded relatively higher correlation rather than other tests. As the visual impairment became stronger, the correlation between age and speed became smaller. However, all tests did not show significant correlation between age and speed.

5 Conclusion

The study focused on the relation between age and evacuation depending on visibility. Subjects between 20 and 49 evacuated, Group B in this study, fastest in general. The impaired visibility slowed down the evacuation speed and cause wide interindividual variability in evacuation results. When the indoor lights were off, the speed was 73% of the normal condition. When visibility reduced by smoke, the speed stood at 38% of the normal condition. In case of the participants aged 50 and older, the variability of evacuation speed depending on visibility was the least. The correlation between age and speed the study analyzed was not significant though it grew bigger when the visibility constraint was weaker.

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