PEDESTRIAN BEHAVIORS ON CROSSWALKS AT INTERSECTIONS IN WINTER

[1]Yoko SHINTANI, [1]Fumihiro HARA, [2]Yoshimitsu HIRAMORI, [3] Motoki ASANO,

[1] Hokkaido Development Engineering Center, #11, South-1, East-2, Chuo-ku, Sapporo, Hokkaido, 060-0051, Japan
Tel: +81-11-271-3028 / Fax: +81-11-271-5115 / E-mail: shintani @decnet.or.jp

[2] Hokkaido Development Bureau, North-2, West-19, Chuo-ku, Sapporo, Hokkaido, 060-8506, Japan
Tel: +81-11-611-0111 / Fax: +81-11-611-0797 / E-mail: takesi-i@hda.go.jp

[3] Civil Engineering Research Institute, Hokkaido Development Bureau
1-3, Hiragishi, Toyohira-ku, Sapporo 062-8602 Japan
Tel: +81-11-841-1111 / Fax: +81-11-841-9747 / E-mail: m-asano@ceri.go.jp

1. Background and Objectives of the Research

The winter climate of northern Japan, characterized by heavy snowfall and relatively low temperature, poses particular difficulty to pedestrians. Snow removed from roads is piled at the roadside, narrowing sidewalks, obstructing the sight vision of pedestrians, and increasing the likelihood of traffic accidents and other accidents involving pedestrians. Also, slippery surfaces increase the likelihood of accidents whereby pedestrians slip and fall (hereinafter, “falling accidents”). Such a walking environment raises the likelihood of accidents for people whose mobility is not otherwise diminished. For the elderly, whose mobility is often diminished, such a walking environment makes conditions more than just uncomfortable: It is a major impediment to their mobility during winter.

Formulation of effective countermeasures against falling accidents first demands clarification of problems of the winter walking environment and causes of falling accidents. Surveys on falling accidents conducted in various fields have reported the degree of injury to the elderly and the significance of constructing a safe walking environment. However, such surveys do not offer fundamental information, such as the numbers of falls and near falls, the attributes of fallers, and the accident locations. The mechanism of falling accidents has therefore not yet been revealed.

The survey results of Merrild and Bak[1)] of Denmark and Oberg[2)] of Sweden include the number of falls and the attributes of fallers based on medical records from hospitals. Their surveys however targeted only comparatively severely injured people, including those who were hospitalized. Surveys by Hara et al.[3)] and Nihonyanagi et al.[4)], analyzed records of ambulance rescue for falling accidents. These surveys focused only on people seriously injured in falling accidents, as are true of the aforementioned surveys. None of these surveys provide information on people who fell but did not go to the hospital or on people who slipped and nearly fell.

Merrild and Bak[1)] and Oberg[2)] surveyed the locations of falling accidents through face-to-face and telephone interviews with injured fallers. Their surveys however did not report the specifics of location, road structure (e.g., center of sidewalk, transition between sidewalk and carriageway), and surface condition. Hara et al.[5)] conducted a questionnaire on women in Sapporo to summarize the number and locations of falling accidents during winter. As in the aforementioned surveys, however, this survey does not provide concrete information on accidents at the time of occurrence. In follow-up surveys, acquired information is not always credible because the memory of the faller is the sole source of information.

In light of the above, this research focuses on downtown Sapporo, especially intersections with the most severe walking environment during winter. A falling accident survey, walking environment survey, and an experiment of walking on a pedestrian crossing during winter were conducted to analyze behavior of pedestrians and causes of falling accidents in winter. This study reports the results, with the aim of improving the winter walking environment such as by suggesting improvements to "barrier-free" intersections and their vicinities.

2. Falling Accident Survey

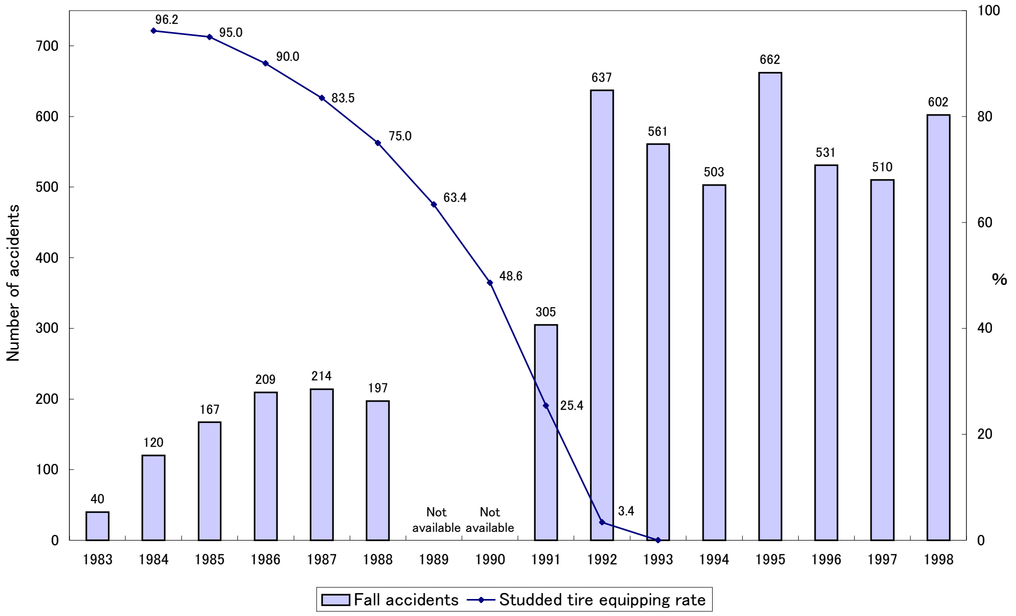
The City of Sapporo banned studded tires in 1991, to eradicate pollution of the dust abraded by them. However, this led to a rapid increase in slippery surfaces, which deteriorated the winter walking environment. Figure 1 summarizes changes in the number of fallers carried by ambulance in winter and the studded tire equipping rate in Sapporo. The figure indicates that approximately 200 accidents occurred every year in the second half of the 1980s, when studded tires were still being used. Since 1992, however, when the transition to studless tires was complete, the yearly number of accidents has increased dramatically to 500-600.

It is very difficult to count every single person who fell or nearly fell in downtown Sapporo and to record the scene and location of every such accident. The locations most prone to falling accidents were identified in order to survey specifics of the walking environment and falling accidents there. For the identification, the number of ambulance rescues for falling accidents in the winters (December to March) of fiscal 1996 through 1999 was sorted on a block-by-block basis (Table 1), because streets run parallel north-south and east-west to form a neat grid in the city center.

It is interesting to note the high distribution of falling accidents at South 4 West 3, which is in the Susukino nightlife district (data exclude the number of fallers sent to the emergency room that operates during the Sapporo Snow Festival held in early February). Since most accidents occurred at night (17:00-6:59), causes are assumed to be not merely icy surfaces and snowfall, but also intoxication of pedestrians. In contrast, falling accidents during daytime (7:00-16:59) are highly distributed at South 2 West 2 and 3, where retails shops, restaurants, and similar business establishments concentrate. A high distribution between 14:00 and 17:00 indicates that most injured fallers are shoppers. Among the 11 fallers at those blocks, 7 were women aged 58 or over. This trend agrees with the conclusion of Hara et al.[5] that “the number of falling pedestrians increases in proportion to age, and accidents are especially numerous for women in their 50's or over.”

In light of the above, a fact-finding survey was conducted on the winter walking environment and specifics of pedestrian behavior in the vicinity of South 2, West 2 and 3, where relatively many falling accidents have been confirmed to occur during daytime. This district was selected over the Susukino district, where intoxication of pedestrians seems responsible for the occurrence of many falling accidents.

Figure 1. Changes in fallers carried by ambulance in winter and the studded tire equipping rate in Sapporo



Source: Fallers is based on the total number between December and February of the relevant fiscal years, derived from ambulance rescue records of Sapporo Fire Bureau, City of Sapporo. The equipping rate is based on surveys by the City of Sapporo for the coldest period of winter.

Table 1. Block-by-block number of ambulance rescues for winter fallers

1996～1999 （December–March）

Daytime（7:00～16:59）

	West 11	West 10	West 9	West 8	West 7	West 6	West 5	West 4	West 3	West 2	West 1	East 1	East 2	East 3	
North 8						2			1			1			North 8
North 7								3			1		1		North 7
North 6				1		1	1	1	5			1	1		North 6
North 5		1			1		1	3		1					North 5
North 4								3	2	2		1			North 4
North 3				1				1	2		1				North 3
North 2					1			1		2		1			North 2
North 1		1		1		1	1	1		2		1			North 1
Odori	2		2	2		6*	1	3	1	1	2	1	1		Odori
South 1	1				1		2	3		**3**	2				South 1
South 2						1	1		**3**	**5**	1	1	1		South 2
South 3			1					1	1	1	1				South 3
South 4			1					2	1	1		1			South 4
South 5			3		1		2								South 5
South 6		1		1	1		1	1	1						South 6
South 7				1			1		1			1			South 7
South 8	1			2	1	2		1	1						South 8
South 9			3	2	1	1		2			1				South 9
South 10		1	1	1	1				1						South 10
	West 11	West 10	West 9	West 8	West 7	West 6	West 5	West 4	West 3	West 2	West 1	East 1	East 2	East 3	

＊Odori–6: A medical emergency room was temporalily placed here for the Snow Festiva

1996～1999 （December–March）

Nighttime（17:00～6:59）

	West 11	West 10	West 9	West 8	West 7	West 6	West 5	West 4	West 3	West 2	West 1	East 1	East 2	East 3	
North 8								2							North 8
North 7	1				1	2		1		1					North 7
North 6								1	5						North 6
North 5					3	1	4	1		2	1				North 5
North 4						1	1	4		1	2				North 4
North 3					1	1	1	2	2		1				North 3
North 2									2	2			2		North 2
North 1	1			1	1		1	3	3	2	2				North 1
Odori		4	2	2	2	32*	4	3	2	3	9				Odori
South 1	2	2		1	1	1	4	3	3	1	1	1	2		South 1
South 2	3	1				3	4	2	3	3	1				South 2
South 3		2		2	3	1	3	3		5	2		2		South 3
South 4		1		1	11		8	15	**36**	5	4				South 4
South 5	3		1	1	3	12	**18**	**25**	14	4	3	1	2		South 5
South 6					2	4	6	9	8	2	1	1			South 6
South 7			1	1	7	3	4	7	4	4	3	2			South 7
South 8			1		1	2	2	2	3						South 8
South 9					1	1		3	6	1	1				South 9
South 10				1	1	3			1		1				South 10
	West 11	West 10	West 9	West 8	West 7	West 6	West 5	West 4	West 3	West 2	West 1	East 1	East 2	East 3	

＊Odori–6: A medical emergency room was temporalily placed here for the Snow Fest

Source: Report on Falling Accidents due to Snow, by the Rescue Section, Fire Prevention and Control Department, Sapporo Fire Bureau

3. Walking Environment Survey

1) Survey on falling accidents by video camera

To accurately reveal the characteristics of pedestrians who fell or nearly fell, we videotaped the locations of falling accidents and near-falling accidents, the conditions of those locations, and the scenes of such accidents, in the survey area (South 1 and 2, West 2). These locations were selected according to the results of the aforementioned falling accident survey. Video cameras were installed on the second floor of commercial buildings at the intersection for a bird's-eye view of one spot each of the east-west and north-south pedestrian crossings, for sex and age recognition from appearance of pedestrians. The recording time of day was the 2 to 3 hours between around 13:30 and 17:00, 2 to 4 times a week from January 9 to February 17, 2001. The total recording time and days are 21 hours 16 minutes and 20 days.

Falls and near falls numbered 213 in the survey period, of which 34 (16%) were falls. Most falling accident locations were steep transitions from sidewalk to ice-covered pedestrian crossing. On January 27, the day on which the number of falling accidents was the greatest in the recording period, the occurrence of falling accidents concentrated at level sections of pedestrian crossings covered with black ice. Also, pedestrians tended to fall or almost fall in succession at the same place (Figure 2).

Table 2 compares the number of pedestrians and that of people who fell or nearly fell at falling-prone locations. The table shows that people who fell or nearly fell account for approximately 5% of all pedestrians. The table also demonstrates that although male pedestrians were fewer than female ones, the number of males who fell or nearly fell was greater than that of females. The age was determined by the surveyors according to appearance. Although it is difficult to confirm the accuracy of the results, they show that falling or near-falling accidents numbered largest for people aged 16-30, who go out more than any other age group (Table 3).

To examine the numbers of falling accidents and near-falling accidents with respect to sex, independence of the population mean was verified by Pearson chi-square according to the following hypotheses:

Hypothesis H1

Null hypothesis $H1_0$: Falling and near-falling accidents occur without respect to sex of pedestrian.

Alternative hypothesis $H1_1$: Falling and near-falling accidents occur with respect to sex of pedestrian.

Table 4 shows that the null hypothesis H1 is not proven for its level of significance (1%), which clarifies that the risk of falling is higher for men than for women.

2) Field survey

Since the video survey on falling accidents targeted only pedestrian crossings, a field survey to inspect danger factors for falling on the sidewalk near the intersection was conducted to supplement the falling accident survey. Inspection courses were designated in three arbitrarily chosen areas. Three pairs of surveyors (a total of six surveyors) walked through different inspection courses to record locations and surface conditions where they felt danger. The course lengths were 300 to 350 m. In designating the courses, utmost effort was made to select sidewalks without winter surface measures, such as road heating. In addition, walking conditions were varied to confirm their impact on the likelihood of falling. The surveyors walked normally, walked fast, carried backpacks weighing approximately 20% of their weight, and walked with one foot in a cast. They recorded situations where they felt danger.

There were no inspection courses where both surveyors fell, but they felt danger in 19 situations. Table 5 shows the number of situations where the surveyors felt danger according to walking condition. Danger was felt most when walking with one foot in a cast, followed by when carrying a heavy backpack.

Locations where danger was felt include pedestrian crossings covered with black ice, steep transition areas and transition areas between the sidewalk and the pedestrian crossing where there are numerous falls, and sidewalks of bridges where the surface temperature is prone to change radically. Among the coefficients of friction measured at dangerous locations, the minimum value (μ) was 0.05, which indicates a very slippery surface (Table 6). A wet surface was formed at the locations with a coefficient of friction of 0.5, and ice films were sporadically distributed there. It is therefore possible to suppose that accurate measurement was difficult.

The sample size of this survey was limited, making accurate quantitative analysis difficult. However, it has been confirmed that characteristics of dangerous surfaces near the intersection and restrictions on walking have a cumulative effect.

Figure 2. Locations of falling accidents in the survey area

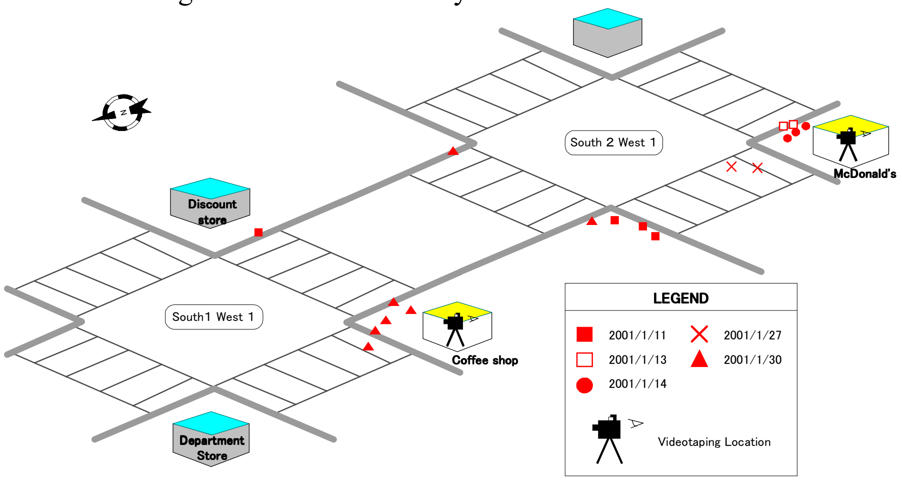


Table 2. Number of fallers and near-fallers by sex (Jan. 27)

		Female	Male	Total
No incident		2375	1754	4129
	%	54.77	40.45	95.23
Slipped and/or fell		82	125	207
	%	1.89	2.88	4.77
Total		2457	1879	4336
	%	56.67	43.33	100

Table 3. Number of fallers and near-fallers by age (Jan. 27)

		Infant	Child	Teens–30's	40's–60's	70's	Total
No incident		53	71	3046	924	35	4129
	%	1.22	1.64	70.25	21.31	0.81	95.23
Slipped and/or fell		2	5	167	29	4	207
	%	0.05	0.12	3.85	0.67	0.09	4.77
Total		55	76	3213	953	39	4336
	%	1.27	1.75	74.10	21.98	0.90	100

Table 4. Verification of independence of the population mean by Pearson chi-square Hypothesis H1

	Value	DF	Asymptotic Sig. (2-tailed)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)	Sig. Level
Pearson Chi-Square (2)	25.739	1	0.000			<0.01
Continuity Correction (1)	25.015	1	0.000			<0.01
Likelihood Ratio	25.473	1	0.000			<0.01
Fisher's Exact Test				0.000	0.000	<0.01
# of Valid Cases	4336					

(1) Computed only for a 2x2 table.
(2) 0 cells (.0%) have expected count less than 5. The minimum expected count is 89.70.

Table 5. Number of situations where danger was felt

Risk Classification		Walking Condition				Total
		Normal	Quick	w/Heavy Backpack	w/Ankle Cast	
0	Walked slowly with caution	0	0	3	1	4
1	Slipped a little but continued walking	2	3	2	7	14
2	Sipped and almost fell	0	0	1	0	1
3	Slipped and fell	0	0	0	0	0
	Total	2	3	6	8	19

Table 6. Coefficient of friction and surface conditions where danger was felt

Course ID	Case ID	Walking Condition ID	Risk Classification ID	Friction Coefficient (13:00)*	Remarks
S1W10	D21	2	0	0.13-0.23	The central part of the pedestrian crossing was slightly bumpy.
	A31	3	1	0.17-0.28	Ice plates, bumps, level differences, and steep slopes were found at the curb ramp.
S4E2	B01	0	1	0.05-0.15	The central part of the pedestrian crossing was flat, but there were ice plates and black ice.
	B11	1	1	0.05-0.15	The central part of the pedestrian crossing was flat, but there were ice plates and black ice.
	D11	1	1	0.05-0.15	The central part of the pedestrian crossing was flat, but there were ice plates and black ice.
	B21	2	1	0.05-0.15	The central part of the pedestrian crossing was flat, but there were ice plates and black ice.
	C20	2	0	0.05-0.15	The central part of the pedestrian crossing was flat, but there were ice plates and black ice.
	D21	2	1	0.17-0.2	Compacted snow, bumps, and steep slopes were found in the center of the sidewalk.
	A31	3	1	0.05-0.15	The central part of the pedestrian crossing was flat, but there were ice plates and black ice.
	B31	3	1	0.05-0.15	The central part of the pedestrian crossing was flat, but there were ice plates and black ice.
	D31	3	1	0.05-0.15	The central part of the pedestrian crossing was flat, but there were ice plates and black ice.
N2E1	B01	0	1	0.36	Ice films were sporadically distributed on the sidewalk of the bridge.
	C11	1	1	0.5	Ice films were sporadically distributed on the sidewalk of the bridge.
	B21	2	0	0.2-0.3	Ice plates, bumps, level differences, and steep slopes were found at the curb ramp.
	B22	2	2	0.5	Bumps and level differences were found in the center of the sidewalk, and slipping occurred on the rough ice film there.
	A31	3	1	0.5	Ice films were sporadically distributed on the sidewalk of the bridge.
	A32	3	1	0.3-0.4	Compacted snow was found in the center of the sidewalk, where the surface was slippery due to snowmelt by sunlight.
	B31	3	1	0.5	Ice films were sporadically distributed on the sidewalk of the bridge.
	D31	3	0	0.5	Ice films were sporadically distributed on the sidewalk of the bridge.
Total			19		

* Coefficient of friction was measured at 1 p.m. of the survey day.

Legend

Risk Classification	
0	Walked slowly with caution
1	Slipped a little but continued walking
2	Sipped and almost fell
3	Slipped and fell

Walking Condition	
0	Normal
1	Quick
2	w/Heavy Backpack
3	w/Ankle Cast

4. Walking Experiment

1) Outline of the experiment

Mano[6], who is researching falls by the elderly from the standpoint of rehabilitation medicine, classifies potential factors for falling accidents into internal and external factors. These are the physical and mental characteristics of pedestrians and the environmental factors surrounding pedestrians, respectively. He has pointed out that many falling accidents are caused by interaction of internal and external factors. On that basis, it can be said that falling on the street in winter is induced by the interaction between internal factors of pedestrians' physical ability and adaptability to the surrounding environment, and external factors of snowy and icy surfaces, steep slopes, level differences, unevenness, etc. Pedestrians whose mobility is not normally impaired fall when the severe winter walking environment (external factor) exceeds their physical limits. Pedestrians such as the elderly and the physically challenged, whose mobility is normally impaired, do not have the physical ability to adapt to the surrounding environment (internal factor). Thus, they often fall due to their inability to fully adapt to the severe winter walking environment.

This walking experiment analyzed the effects of external factors considered responsible for falling which transcend the physical ability of pedestrians (non-mobility-impaired), then analyzed causes of falling of the elderly and the physically challenged (mobility-impaired).

This experiment was conducted on an outdoor walkway modeled after a sidewalk during winter (Figure 3). The surface conditions of this walkway can be changed between snowy, icy, and snowless. The cross slope and grade of the walkway are also variable. Since various external factors were anticipated, the factors subject to the survey were limited to level of slipperiness and gradient of the surface. Combinations of gradients were determined based on the orthogonal array, for the sake of efficiency (Tables 7 and 9). The subjects were 13 healthy people in their 20's (6 male, 7 female). Walking velocities of round-trips on the same walkway were measured under different conditions, and walking behavior was recorded (Table 8).

2) Analysis

(1) Walking speed

Walking speeds of the subjects were compared with respect to gradient and surface condition (Figure 4 (1)). The figure shows that the walking speed is almost constant on the snowless surface without respect to gradient and that it varies greatly on the icy surface with respect to gradient. A decrease in walking speed is particularly noticeable when the gradient condition (hereinafter, “GC”) is 3, 6, 8, and 9. The walking speeds on the pedestrian crossing section were compared, with respect to combined gradient of the pedestrian crossing section (Figure 4(2)). The figure shows that the walking speed decreases when the combined gradient equals or exceeds 8.25% and that the walking speeds of the subjects are widely distributed.

On the icy surface, the walking speed was compared with respect to cross slope and grade in order to identify gradient values causing changes in walking speed (Figures 4(3), 4(4), and 4(5)). The comparison indicates that the walking speed is prone to decrease with an increase in the cross slope rather than in grade, both on the pedestrian crossing section and on the sidewalk section. The rate of decrease in the walking speed as the cross slope increases in the range of 5% to 8% is greater than the rate of decrease in any other range. When the cross slope equals or exceeds 5%, the walking speed is likely to be profoundly affected. In addition, the walking speed was compared with respect to combined gradient of the sidewalk section (Figure 4(6)). However, the trend of cross slope is not observed in the figure.

The average walking speed is less when the cross slope and grade are both 0% than when they are 2%. Since the incipient phase of the experiment was walking on the flat icy surface, it is possible that the subjects were not used to the experimental walkway.

(2) Number of instances of falling / walking interruption

There were 9 instances in which the subjects fell / suffered walking interruption on the icy surface during the walking experiment. Table 10 shows that the risk of falling / walking interruption increases as the cross slope increases. Conversely, it seems that falling / walking interruption occurs without respect to the grade of carriageway.

(3) Effects of cross slope on the ratio of time on two feet on the icy surface

The cross slope is considered more likely than the grade to be responsible for falling on the icy surface. The reasons are a great decrease in the walking speed of subjects and an increase in the number of instances of falling / walking interruption as the cross slope increases. The ratio of time on two feet on the icy surface was compared between two gradient conditions, whose combined gradients on carriageway are equal, to study the effects of cross slope and grade on walking behavior. Specifically, the ratio of time on two feet (double supporting period) on the icy surface was compared between GC2 and 4, GC 3 and 7, and GC 6 and 8. (Table 11). Figure 5 defines the ratio of time on two feet on the icy surface as the ratio of time on two feet on the icy surface per walking cycle (=two strides) to the total time on the icy surface per walking cycle. For example, the ratio is 0% when the subject is running. When the subject is having great difficulty walking (reeling), the ratio approaches 100%. If the ratio is larger at certain values of gradient, it suggests that the subject is walking under difficult conditions.

Table 11 compares the average ratio of the time on two feet on the icy surface with respect to combination of gradients. When the cross slope exceeds the grade, the ratio is large, despite the equality of combined gradients (GC2, 3, and 6). The independence of the population mean was verified by T-test, based on the following hypotheses:

Hypothesis H1: Combined gradient of the carriageway of GC2 and 4 is 5.39%.

Null hypothesis $H1_0$: The ratio of the time on two feet on the icy surface of GC2 is equal to that of GC4.

Alternative hypothesis $H1_1$: The ratio of the time on two feet on the icy surface of GC 2 exceeds that of GC4.

Hypothesis H2: Combined gradient of the carriageway of GC3 and 7 is 8.25%.

Null hypothesis $H2_0$: The ratio of the time on two feet on the icy surface of GC3 is equal to that of GC7.

Alternative hypothesis $H2_1$: The ratio of the time on two feet on the icy surface of GC3 exceeds that of GC7.

Hypothesis H3: Combined gradient of the carriageway of GC 6 and 8 is 9.43%.

Null hypothesis $H3_0$: The ratio of the time on two feet on the icy surface of GC6 is equal to that of GC8.

Alternative hypothesis $H3_1$: The ratio of the time on two feet on the icy surface of GC6 exceeds that of GC8.

Table 12 shows that null hypothesis H4 is not proven for its level of significance (1%). The table also confirms that the effects of cross slope on the walking behavior of the subjects are larger than those of grade, because the ratio of the time on two feet on the icy surface of GC3 exceeds that of GC7. Conversely, the null hypotheses H3 and H5 are not disproven for their levels of significance. Therefore, the effects of grade are assumed to be similar to those of cross slope on the surface where the combined gradient is smaller than 8.25% or is 9.4%

Figure 3. Experimental walkway with variable gradient

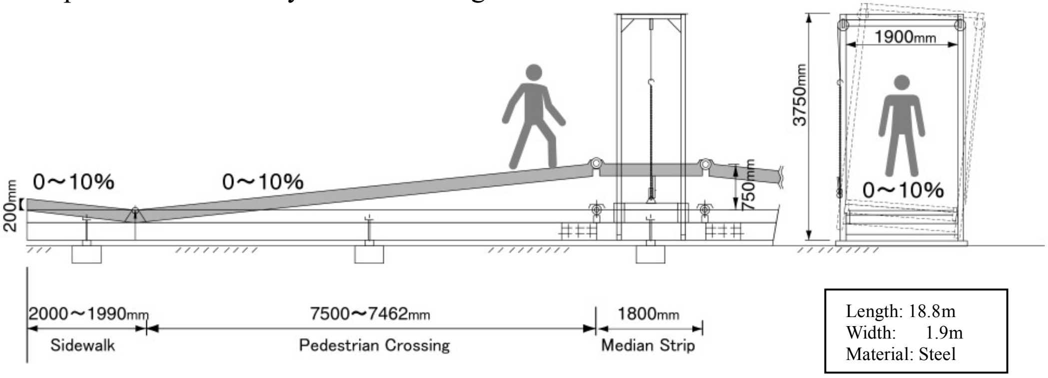


Table 7. Factors subject to the survey, and their levels

Factor			Level			
Explanatory Variable	Surface Condition	Classification	Icy/Slippery		Normal	
		Friction Coefficient	< 0.25		> 0.5	
	Grade	Crossing	0%	2%	5%	8%
		Sidewalk	0%	2%	5%	8%
	Cross Slope	Crossing/ Sidewalk	0%	2%	5%	8%

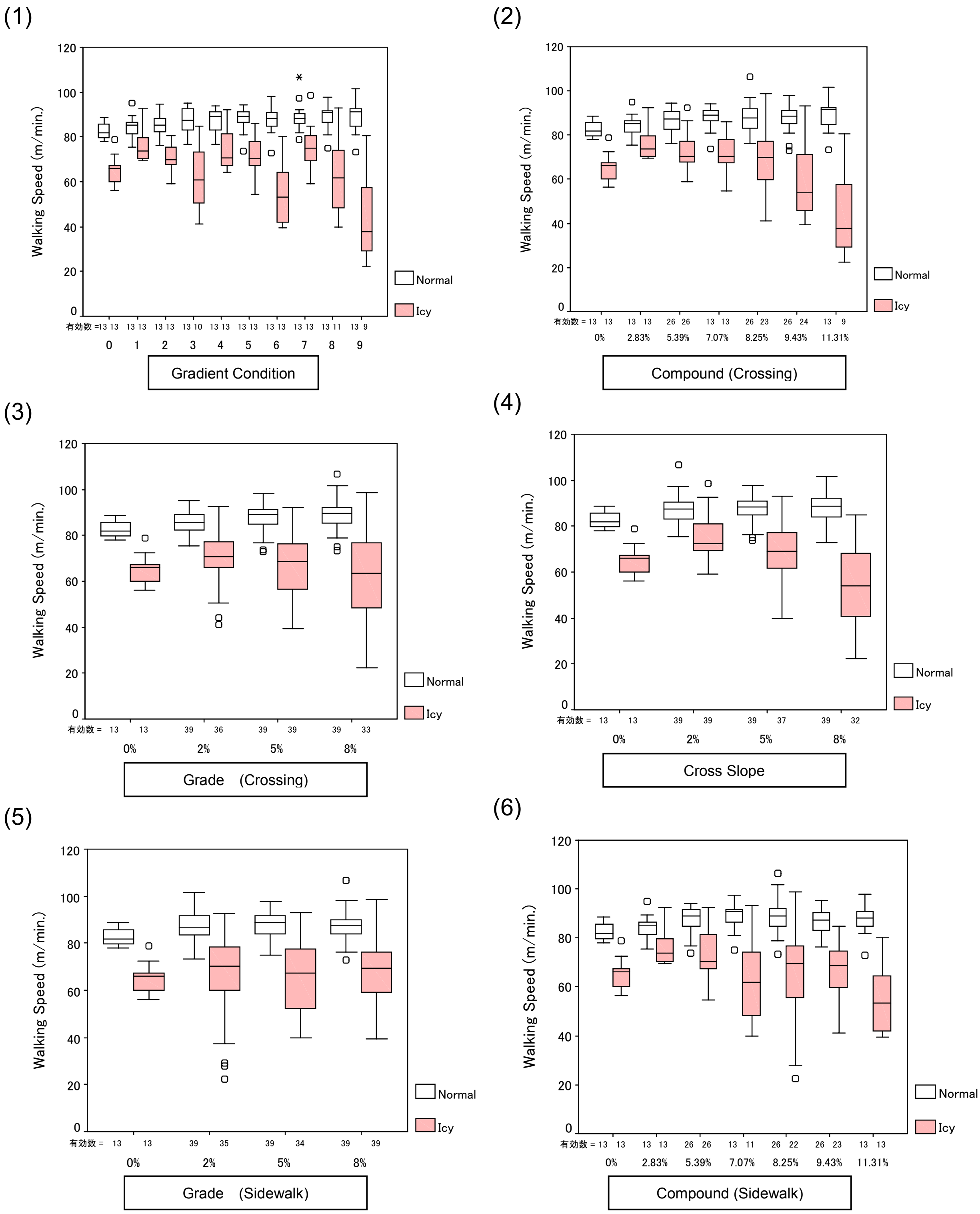
Table 8. Measurement items

	Measurement Item
Criterion Variable	Walking Speed (m/min.)
	Number of falls / walking interruptions
	Ratio of double supporting period (%)

Table 9. Gradient Conditions

Gradient Condition		0	1	2	3	4	5	6	7	8	9
Grade	Crossing	0%	2%	2%	2%	5%	5%	5%	8%	8%	8%
	Sidewalk	0%	2%	8%	5%	5%	2%	8%	8%	5%	2%
Cross Slope	C/S	0%	2%	5%	8%	2%	5%	8%	2%	5%	8%
Compound	Crossing	0%	2.83%	5.39%	8.25%	5.39%	7.07%	9.43%	8.25%	9.43%	11.31%
	Sidewalk	0%	2.83%	9.43%	9.43%	5.39%	5.39%	11.31%	8.25%	7.07%	8.25%

Figure 4. Distribution of walking speed with respect to gradient and surface condition



<Box-and-whisker plot>

- This simplified diagram is based on median, quartile, and outlier. The box is in the inter-quartile range and contains 50% of the relevant data.
- The lines (whiskers) radiate from the boxes toward the values that are largest and smallest, excluding the outliers, and show the distribution range.
- The circles, asterisks, and the horizontal lines in the boxes denote outlier, extreme value, and median, respectively.

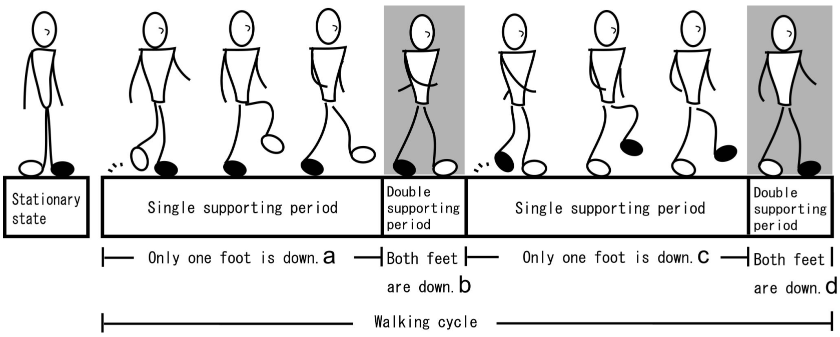
Table 10. Numbers of instances of falling / walking interruption, with respect to cross slope and grade

Horizontal	No accident	Accident*	Total
0%	13	0	13
2%	39	0	39
5%	37	2	39
8%	32	7	39
Total	121	9	130
%	93.1	6.9	100

Vertical (Crossing)	No accident	Accident*	Total
0%	13	0	13
2%	36	3	39
5%	39	0	39
8%	33	6	39
Total	121	9	130
%	93.1	6.9	100

*Number of slipped & fell and/or interruptions while walking on icy walkway.

Figure 5. Definition of the ratio of time on two feet



Ratio of time on two feet = [(b/a+ b) + (d/c+d)] / 2* 100

Table 11. Rate of support by two feet, by gradient

Gradient Condition				N	Mean ratio of support by two feet (%)	Std. Deviation	Std. Error Mean
GC	Horizontal	Vertical (crossing)	Compound				
2	5%	2%	5.39%	13	23.014	5.087	1.411
4	2%	5%		13	22.339	4.480	1.243
3	8%	2%	8.25%	13	30.470	6.566	1.821
7	2%	8%		13	23.490	6.213	1.723
6	8%	5%	9.43%	13	30.339	4.974	1.380
8	5%	8%		13	27.262	6.233	1.729

Table 12. Verification of differences in the two population means by T-test

Gradient Condition		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	DF	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Mean Lower	Upper
2-4	Equal variances assumed	0.097	0.758	0.359	24	0.723	0.675	1.88	-3.206	4.555
	Equal variances not assumed			0.359	23.623	0.723	0.675	1.88	-3.209	4.559
3-7	Equal variances assumed	0.147	0.705	2.784	24	0.010	6.980	2.507	1.806	12.155
	Equal variances not assumed			2.784	23.927	0.010	6.980	2.507	1.805	12.156
6-8	Equal variances assumed	0.527	0.475	1.391	24	0.177	3.077	2.212	-1.488	7.642
	Equal variances not assumed			1.391	22.875	0.178	3.077	2.212	-1.500	7.654

5. Conclusions

As a result of the surveys above, the following conclusions were reached.

- Falling accidents frequently occur at night in the entertainment district during winter. It is not only the icy surface and snowfall that are responsible for accidents, but so is the intoxication of pedestrians.
- Falling accidents often take place during daytime in districts where commercial establishments concentrate. Shopping districts are considered to account for a major share of pedestrian falls.
- Many falling accidents occur at the transition between pedestrian crossing and ice-covered sidewalk, as well as on black-ice-covered pedestrian crossings.
- When pedestrians walk on the icy surface, their walking speed and way of walking are considerably changed by an increase in the cross slope. When the combined gradient is approximately 8 to 9% and the transverse gradient exceeds the grade, the likelihood of difficult walking conditions increases to a particularly great degree for pedestrians.
- Risk by age is not clearly reflected in the survey results. The survey results concerning the risk by sex suggest that likelihood of falling accident is greater for men than for women, which does not agree with Merrild et al.(1), Hara et al.(3), and Hara et al.(5) A possible reason is that those studies did not always limit their focus to seriously injured fallers. Therefore, although the risk of falling is higher for men, it is fair to say that

women fallers are more likely to suffer serious injury.

In view of these results, the following proposals, including making the intersection and its vicinity "barrier-free" during winter, are made to advance improvement of the winter walking environment.

- The video survey results confirmed that many falling accidents occur on transition areas between the sidewalk and the pedestrian crossing at intersections. In many of such areas, the slopes are steep and uneven, and a high degree of steepness results from differences in the level of snow removal on the sidewalk and the pedestrian crossing. When the combined gradient equals or exceeds 8%, which is a value experimentally determined to be dangerous, the dangerous effect of the cross slope of the transition area is assumed to be much greater than the grade. A possible countermeasure is to change the intersection structure to remove uneven spots on the surface and reduce the combined gradient of transition to 9% or below. The cross slope, in particular, should be decreased as much as possible. If structural change is not feasible due to land use restrictions, installation of snow-melting facilities, such as road heating, needs to be examined.
- Falling also takes place frequently on black-ice-covered surfaces of the pedestrian crossing. Even when the level of snow removal is higher than that of the sidewalk and measures are taken for the surface, pedestrians often fall at spots with low coefficients of friction. In such cases, extensive road surface management of carriageways (application of anti-freezing agents) is most important. However, snow-melting facilities, freezing-prevention pavement, or other measures must be studied for pedestrian crossings where slippery road surfaces frequently form by large traffic volume and shade of buildings.
- The falling risk is largely irrespective of age. The risk is higher for men than for women, but the likelihood of serious injury is higher for women. It is therefore necessary to take measures to prevent all types of pedestrians from falling. However, municipalities in cold, snowy regions devote a large portion of their budgets to winter road surface management, so budgets are limited for facility- and equipment-based measures to improve the walking environment. Selection and implementation of such measures must therefore address all relevant aspects, such as land use, pedestrian volume, the number of traffic accidents, and construction, maintenance, and management costs. Improvement of non-equipment and non-facility aspects also is imperative. For example, pedestrians themselves should take measures to prevent falling by changing their way of walking and transportation means depending on their physical ability.

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