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Original Article

A Study of Cognitive Slips According to Contaminants on the Floor

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A R T I C L E I N F O

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A B S T R A C T

Background: This research investigates the degrees of slipperiness felt by the participants who walk on contaminants applied to a floor surface to decide degrees of slipperiness for various contaminants.
Methods: For the experiment, 30 participants walked on a floor to which six contaminants were applied. All participants took the analytic hierarchy process (AHP)–based slipperiness questionnaire survey for the six kinds of contaminants, and the results were compared with the coefficient of friction.
Results: The results of slip risk from the AHP indicate that grease is the most slippery of the six contaminants, followed by diesel engine oil, hydraulic oil, cooking oil, water-soluble cutting oil, and water in a decreasing order of slipperiness. When the results of slip risk from the AHP are compared with the static coefficient of friction for each contaminant, the order of slip risk follows the same trend. Although the results of slip risk from the AHP coincide with the static coefficient of friction, further study would be needed to investigate this relationship.
Conclusion: This study will contribute as reference material for future research on preventing industrial accidents that result in falls from high places due to slipping.

1. Introduction

In Republic of Korea, as reported by the Ministry of Employment and Labor in 2015, the rate of casualties due to slip, trip, and fall at the same level is approximately 17.34% (15,632) of all casualties from industrial accidents (90,129) [1]. These accidents are caused by slip, trip, and misstep due to wet or otherwise dangerous floors [2]. It is possible that these accidents occurred as a result of contaminants on the floor surfaces. Republic of Korea has no appropriate regulations on slip accidents caused by contaminants on floor surfaces.

Some international standards (e.g., BS EN ISO 13287: 2007 "Personal Protective Equipment. Footwear, Test Method for Slip Resistance") have adopted a concept of standard contaminant as a measurement standard of the coefficient of friction and slip resistance and specified glycerol and detergent solutions as the standard contaminants[2]. Primary risk factors of slip are characteristics of flooring material, shapes and conditions of abrasion of footwear, activities of the individual, degree of visibility or quality of lighting, conditions of accidents, types and presence of contaminants, and so forth [3]. Contaminants on the floor surface lead to 80% or more of injuries caused by losing one's footing due to a slip [3]. The coefficient of friction is the commonly used physical quantity to express slip resistance. Various devices and techniques have been used to measure slip resistance, but slip experiments on humans depend on researchers' subjective judgment or psychological evaluation and are difficult to measure because pedestrians' risk cognition changes their style of walking[4]. To solve these problems, some studies assumed that a slip is related to humans' cognitive judgment[4].

Therefore, this research investigates normal pedestrians' perception of various contaminants on standard flooring materials that can exist in workplaces by conducting relative analytic hierarchy process (AHP)–based questionnaire surveys of slip test [5] and identifying the correlation between the results of AHP and the coefficient of friction; the results can be used as research material for the prevention of industrial accidents resulting from slips.

This research aims to investigate the degrees of slipperiness felt by the participants walking on contaminants applied to a floor surface, to decide the degree and rank of slipperiness for six contaminants, and to identify the correlation between the pedestrian's cognition of slipperiness and the actual slipperiness based on the coefficient of friction.

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B. Purposes

2. Materials and methods

2.1. Experimental conditions and participants

Thirty individuals (15 male and 15 female) participated in the experiment. The age range was 20–50 years. The experiment consisted of eight participants (male and female) in their 20s, eight participants (male and female) in their 30s, eight participants (male and female) in their 40s, and six participants (male and female) in their 50s.

Before the experiment, the purpose of this study was explained to all participants who have given their consent for participation. We also confirmed whether the participants have any physical problem(s) and whether they are normal pedestrians before their participation in the study.

This research used one type of footwear in various sizes, recognizing that slipperiness can vary according to types of the sole used in the footwear. We selected footwear that is generally worn by people with identical soles.

2.2. Pedestrian passage for measurement

For the standard flooring, we used stainless steel plates whose surface roughness is 1.6–2.5 μm, as specified in BS-EN13287: 2004 and ISO-EN13287 [2]. To maintain a sufficient walking distance, we designed a pedestrian passage of 1.2 m in length and 0.6 m in width. Because the surface roughness of the flooring material is a very important control variable, we ground the surface periodically with the #100 emery paper to maintain a certain roughness. Fig. 1 shows angle straps installed on the sides of the pedestrian passage to prevent the participants from slipping due to contaminants on the floor during experiments. The use of #100 emery paper satisfies the standard of surface roughness (1.6–2.5 μm) recommended by EN13287 (Fig. 2).

2.3. Questionnaire

The research team prepared a questionnaire to determine the degrees of slipperiness felt by the participants for the six substances. The questionnaire consists of questions related to participants' physical characteristics and a relative evaluation questionnaire for contaminants in pairs. The relative evaluation questionnaire consists of 15 items. The following seven scales were used as responses to the survey question "Do you think A is more slippery than B?": "① very slippery" (4 points), "② slippery" (3 points), "③ slightly slippery" (2 points), "④ moderate" (1 point), "⑤ rarely slippery" (1/2 point), "⑥ not slippery" (1/3 point), and "⑦ never slippery" (1/4 point).

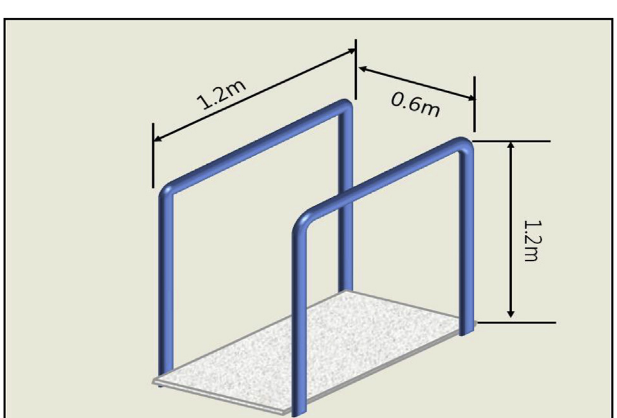

Fig. 1. An illustration of the footpath.

2.4. Experimental measurement

In this study, the participants wore an identical type of footwear in various sizes while walking on the pedestrian passage to exclude external influences. Experiments were conducted under identical conditions (temperature at 19°C ± 2.5°C and humidity of 71% relative humidity (RH) ± 5%) to control the change in viscosity caused by the temperature and humidity of contaminants. Safety was maximized by installing angle straps on the sides of the pedestrian passage to prevent the participants from falling on the floor during the experiments. Because pedestrians' risk cognition can change their styles of walking, the angle straps enabled the participants to walk on the pedestrian passage as naturally as possible.

The participants walked on two pedestrian passages to which the contaminants were applied and then immediately filled the relative evaluation questionnaire.

3. Theory

3.1. Analytic hierarchy process

The AHP is a decision-making technique developed in the 1970s for safety. It is a method to choose an alternative or to decide a priority, together with a decision-making analysis [6,7]. The AHP method is to crosscorrelate two factors through a paired comparison [6]. The calculation method is to obtain the ratio of each line from the sum after obtaining the answer of matrix by multiplying two matrices and adding up the lines [6].

$$(AB)_{ij} = \sum_k A_{ik}B_{kj} \tag{1}$$

where AB_{ij}: matrix multiplication ($m \times n$); A_{ik}: matrix ($m \times k$); B_{kj}: matrix ($k \times n$); i: 1, 2 …, m; j: 1, 2, … , n; and k: 1, 2, …, k.

The value of Equation (1) is between 0 and 1, which is a relative weight where the sum of the coefficients is 1 [6]. This method is adopted under the assumption that all people feel slipperiness on a professional level [7]. The results obtained from the AHP are not reliable until the sum of coefficients is 1.00 and the consistency index (CI) of each participant is less than 0.1. The CI is an index that indicates the degree of consistency with which the participant fills the questionnaire. This index is used to identify logical inconsistency in the participants' responses [6]. Because the survey results are not reliable when the CI is 0.1 or more [6], it is necessary to decide the rank of the degree of slipperiness of contaminants after excluding survey results with values of 0.1 or more.

4. Results and discussion

4.1. Relative evaluation questionnaire analysis

To analyze an AHP technique, we used an analysis software program developed using Microsoft Excel [6]. Table 1 shows each participant's AHP analysis results and CI values. Although the individual survey results depend on each participant, the average score of AHP for six contaminants ranged from 0.051 to 0.195. Most participants, except four, had CI values less than 0.1.

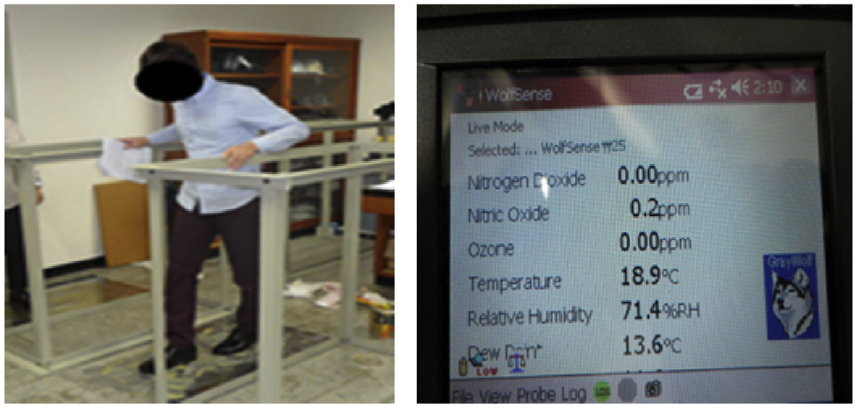

Fig. 2. The footpath used for walking and the conditions maintained during the experiment.

Table 1
Survey results and CI values

No	Water	Cooking oil	Hydraulic oil	Water-soluble cutting oil	Grease	Diesel engine oil	CI
1	0.044	0.115	0.163	0.142	0.374	0.163	0.0443
2	0.041	0.084	0.149	0.159	0.377	0.190	0.0981
3	0.040	0.084	0.140	0.180	0.384	0.172	0.1130
4	0.043	0.111	0.182	0.111	0.371	0.182	0.0500
5	0.049	0.173	0.159	0.083	0.305	0.230	0.0895
6	0.049	0.111	0.168	0.176	0.355	0.141	0.0304
7	0.053	0.105	0.211	0.211	0.211	0.211	0.0000
8	0.057	0.123	0.139	0.063	0.381	0.236	0.0468
9	0.050	0.200	0.130	0.057	0.351	0.212	0.0912
10	0.056	0.212	0.128	0.059	0.358	0.186	0.0629
11	0.049	0.183	0.115	0.060	0.368	0.225	0.1031
12	0.061	0.132	0.197	0.061	0.360	0.188	0.0319
13	0.052	0.133	0.182	0.061	0.339	0.234	0.0533
14	0.060	0.142	0.156	0.060	0.405	0.177	0.0439
15	0.043	0.099	0.142	0.142	0.368	0.206	0.0608
16	0.040	0.082	0.142	0.148	0.411	0.177	0.1154
17	0.040	0.077	0.173	0.111	0.426	0.173	0.0912
18	0.140	0.140	0.122	0.173	0.257	0.168	0.0933
19	0.058	0.125	0.196	0.174	0.280	0.166	0.0634
20	0.043	0.111	0.182	0.111	0.371	0.182	0.0500
21	0.056	0.118	0.183	0.105	0.370	0.169	0.0648
22	0.040	0.075	0.099	0.190	0.327	0.270	0.0897
23	0.040	0.107	0.164	0.065	0.385	0.239	0.1656
24	0.042	0.120	0.134	0.102	0.330	0.271	0.0801
25	0.044	0.087	0.163	0.144	0.417	0.145	0.0677
26	0.041	0.090	0.175	0.118	0.361	0.214	0.0800
27	0.043	0.111	0.182	0.111	0.371	0.182	0.0500
28	0.041	0.095	0.137	0.155	0.401	0.171	0.0903
29	0.059	0.097	0.199	0.083	0.349	0.213	0.0514
30	0.055	0.166	0.156	0.064	0.405	0.153	0.0395
Avg	0.051	0.120	0.159	0.116	0.359	0.1948	0.0704

AHP, analytic hierarchy process; CI, consistency index.

Table 2
Contaminant's AHP rank

Contaminant	AHP rank
Grease	0.355
Diesel engine oil	0.1935
Hydraulic oil	0.162
Cooking oil	0.121
Water-soluble cutting oil	0.117
Water	0.052

AHP, analytic hierarchy process.

Table 2 shows that the participants recognize grease (0.355) as the most slippery substance, followed by diesel engine oil (0.193), hydraulic oil (0.162), cooking oil (0.121), water-soluble cutting oil (0.117), and water (0.052).

Table 3 shows the analysis of the comparative survey results of both male and female participants. Although the survey results differ for male and female participants, both identified grease as the most slippery substance. However, when water-soluble cutting oil and cooking oil were evaluated, female and male participants gave different responses. Female participants perceived water-soluble cutting oil to be more slippery than cooking oil, whereas an opposite trend was noted in male participants. On the basis of these results, although the reason for this trend is unclear, we see that the male and female participants have a different response depending on the contaminants. Further study would be needed to investigate this relationship.

4.2. Comparison of evaluation questionnaire analysis and coefficient of friction

In 2010, Korea Occupational Safety and Health Agency investigated the slip risk of contaminants on the floor [2]. They measured the coefficient of friction of the contaminants on the floor. The coefficient of friction is the commonly used physical quantity to express slip resistance, and it is divided into two indexes: static coefficient of friction (SCoF) and dynamic coefficient of friction (DCoF).

Fig. 3 shows the values of the SCoF and the DCoF for each contaminant [2]. Water had the highest SCoF value, followed by water-soluble cutting oil, cooking oil, machine oil, diesel engine oil, and grease. On the other hand, grease had the highest DCoF value.

To investigate the relationship between the psychological and physical evaluation, the survey results (psychological evaluation) were compared with both the SCoF and DCoF (physical evaluation).

Table 3
Comparison of survey results for female and male participants

Female		Male	
Contaminant	AHP rank	Contaminant	AHP rank
Grease	0.359	Grease	0.350
Diesel engine oil	0.180	Diesel engine oil	0.204
Hydraulic oil	0.167	Hydraulic oil	0.156
Water-soluble cutting oil	0.132	Cooking oil	0.137
Cooking oil	0.107	Water-soluble cutting oil	0.102
Water	0.054	Water	0.051

AHP, analytic hierarchy process.

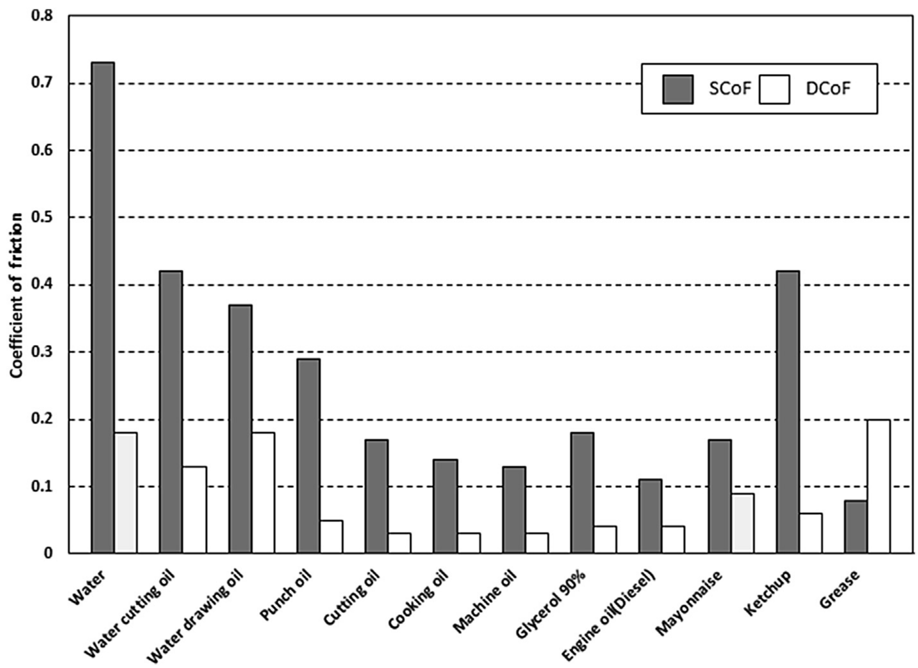

Fig. 3. Slip resistance due to contaminants. DCoF, dynamic coefficient of friction; SCoF, static coefficient of friction.

Table 4
Contaminants' SCoF rank

Contaminant	SCoF rank
Grease	1
Engine oil (diesel)	2
Machine oil	3
Cooking oil	4
Water-soluble cutting oil	5
Water	6

SCoF, static coefficient of friction.

When the results of AHP (Table 2) were compared with the SCoF (Table 4) for the same contaminants, both results showed the same trend, whereas when the results of AHP (Table 2) were compared with that of DCoF (Fig. 3) for the same contaminants, both results did not show the same trend. Although the results of slip risk from AHP coincide with the SCoF, further study would be needed to investigate this relationship.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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