

The Relationship between Weather Conditions and Hiking Safety

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Abstract

Due to COVID-19, more people are participating in outdoor activities like hiking. This study investigated the relationship between weather and hiking accidents at Bukhansan Mountain National Park, a Guinness World Record holder for the most visited national park per unit area. Data analyzed included the number of hikers, accident type, and weather information. Data were collected from the last three years. The results showed the highest number of people took up hiking in 2020 (3,394,413). Accidents were classified into six types: fall, personal disease, distress, attempted suicide, loss of footing (carelessness), and natural disasters. Lost footing caused the largest number of accidents (N=274 cases). For weather-related factors, accidents were more common when the temperature was between 16–28 °C, a humidity of 60–65%, and winds of 6–8 km/h, which are actually considered the ideal conditions for hiking. Therefore, public campaigns or educational information should communicate that ideal weather conditions are actually the most dangerous and risky for hiking accidents. Additionally, the management team and government should inform hikers through signs, course guides, and electronic displays installed in the park. Moreover, hikers should be cautious when hiking and be more aware of their surroundings and environment.

Keywords – Outdoor activities, safety, mountain climbing, weather, climate change

INTRODUCTION

Hiking is one of the most popular outdoor activities worldwide. In South Korea, hiking is the most popular outdoor leisure activity. A survey indicated that 462 million people hike annually. Therefore, there are always concerns about safety accidents in crowded places. At present, social activities are constrained because of COVID-19, so more people are engaging in outdoor activities (Kim & Cho, 2020; Saidan et al., 2020), and hiking

has seen the largest increasing trend amongst outdoor activities (Bård, 2020; Holly, 2020; Venter, Barton, Figari, & Nowell, 2020). The New York Times reported that owing to this, injury risks will increase as more and more people go outdoors to hike. Therefore, precautions should be taken to avoid accidents (Gillian, 2020).

Responding to accidents is important, but it is also crucial to prevent accidents in the first place. To prevent hiking accidents, the accident types must be classified and understood. Analyzing accident types will help the public understand their characteristics and provide effective preventive measures. It was reported that more specific information about such accidents makes it easier for prevention teams and mountain hikers to obtain target information and thereby lower the accident rate.

Even though people imagine 'death' when they think about accidents (Pless, Hagel, Patel, Leduc, & Magdalinos, 2007), this does not contribute to preventive measures. Additionally, there is a tendency for people to think that public accidents result from imperfect or unscientific faith (Torell & Bremberg, 1995). There are research findings that show that this incorrect perception can heighten safety-related accident risk and there is a high

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Declarations:

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Consent for publication - N/A

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correlation between incorrect risk awareness and actual risk (Lestari, Sunindijo, Loosemore, Kusminanti, & Widanarko, 2020). Accordingly, it is very important to classify hiking accident types and convey accurate information to people in a way that they can understand.

Various factors cause hiking accidents. They can happen because of weak physical strength, hiking technique, or partner's abilities. They can also be caused by natural elements like wild animals, weather, and geographical features. Importantly, weather cannot be controlled, unlike other factors, so it requires a greater amount of data collection and analysis.

Research findings showed that weather causes both a direct and indirect influence on many different types of accidents (Bergel-Hayat, Debarh, Antoniou, & Yannis, 2013; Bogalecka & Kołowrocki, 2018; Cho, Kim, & Cha, 2015). Hiking is also affected by weather conditions. There are limitations to hiking on days with heavy snow, rainfall, sudden showers, or thick fog. Additionally, hikers can ensure they wear protective equipment in agreement with the temperature. However, only simple weather information is provided and there are insufficient studies on the correlation between weather conditions and accidents. Therefore, it is necessary to investigate accident types and nature to provide specific, accurate information that could effectively prevent more hiking accidents. As many people are now hiking due to the COVID-19 pandemic, the results will positively influence hikers by providing preventive learning and basic data that can be applied to prevent safety accidents.

MATERIALS AND METHODS

Research sample

There are three major types of data used in this study including the number of hikers as measured by the Bukhansan National Park Service from January 1, 2018, to October 31, 2020, the weather information as measured by the Korea Meteorological Administration, and accident records on Bukhansan Mountain as recorded by the dispatched hiking rescue team and 119 Rescue Center. In total, 519 hiking accident records were used. For the 519 hiking accidents, the accident records of the dispatched hiking rescue team of Bukhansan National Park and 119 Rescue Center were compared and false reports and animal rescue were not included in the research data.

Data collection

Weather

Weather information was provided by the Korea

Meteorological Administration (<https://www.weather.go.kr/w/index.do>). Data from January 1, 2018, to October 31, 2020, were collected. The information from three towers located near Bukhansan Mountain was used to represent the weather faced by hikers at Bukhansan Mountain National Park. Moreover, data that were identified as an equipment check, observation error, and equipment error were calculated as missing values. The temperature, humidity, cloud cover, and wind measurement values recorded by the Korea Meteorological Administration were included in the final analysis.

Bukhansan Mountain National Park hiking accidents

For hiking accidents at Bukhansan Mountain National Park, data from three years, January 1, 2018, to October 31, 2020, was used. For the data about hiking accidents, requests were made to the special 119 rescue team affiliated to the National Fire Agency under the Ministry of Public Safety and Security and the hiking accident database of the Bukhansan Mountain National Park Service Office under a public institution called Korea National Park Service. In addition, a request was made to make a disclosure of the daily records of Bukhansan police mountain rescue affiliated to Seoul Metropolitan Police Agency under the National Police Agency, the central administrative agency, and data was collected. After removing duplicates, 591 data were analyzed.

Bukhansan Mountain attendance

Bukhansan Mountain attendance was based on the integrated number of daily visitors counted by the Bukhansan Mountain National Park Service during the study period. Attendance was also collected from a national intelligence opening service. A total of 9,655,936 people visited.

Data Analysis

This study conducted a literature review based on preceding data and a questionnaire survey in parallel. To secure the reliability of the data, a special request was made to the special 119 rescue team for processed data and it was identified through a weather expert. To analyze the accident types according to weather conditions, SPSS version 26.0 was used for data mining and it was organized into a form to make statistical analysis possible. Descriptive statistics and frequency analysis were conducted to examine the relationship between weather factors (temperature, humidity, wind velocity, cloud cover, precipitation), and accident

types. To determine the accident types for the nominal scale, a cross-tabulation analysis was conducted. The deduced value was proposed through the SPSS graphic chart.

RESULTS

Table 1 shows the number of visitors to Bukhansan National Park from 2018 to 2020. In order to investigate their characteristics, frequency analysis was conducted for the monthly attendance average from January 2018 to October 2020. The analytical findings showed that the highest number of hikers was in April 2020 with 449,068 people, followed by 427,418 people in October 2020. The yearly analytical findings showed that 2020 had the highest number of hikers with 3,394,413 people and the most popular month was October with 1,109,941 people, followed by May with 1,007,467 people. The least popular month was December with 418,021 people but note that the data for November and December 2020 was not included.

Table 2 and Figure 1 shows the weather characteristics of Bukhansan National Park from 2018 to 2020. The weather records for Bukhansan Mountain show that the highest average temperature was 15.94 °C in 2020 and the hottest day was 33.10 °C in 2018. Humidity was highest in 2020 with an average of 62.27% and the cloud cover was highest in 2020 at 4.72. The wind velocity was highest in 2020 with an average of 8.31 km/h.

Table 3 shows seasonal weather characteristics. Based on the observation of the seasonal weather characteristics from 2018 to 2020, the characteristics of spring included an average temperature of 7.66 °C, a humidity of 48.88%, cloud cover of 4.01, wind velocity of 7.95 km/h, and precipitation of 0.57 mm and compared to other seasons, it was windier and had the least amount of rainfall and cloud coverage. In summer, characteristics included an average temperature of 23.88 °C, a humidity of 61.23%, cloud cover of 5.24, wind velocity of 6.66 km/h, and precipitation of 1.32 mm. Additionally, the temperature was the highest and had the most cloud cover compared to other seasons. In winter, the characteristics included the average temperature of 2.09 °C, a humidity of 53.07%, cloud cover of 4.09, wind velocity of 6.61 km/h, and precipitation of 0.78 mm.

To identify hiking accident characteristics for the period 2018 to 2020, frequency analysis was performed based on the month, date, time, accident type, accident form, and season. Table 4 shows the characteristics of annual mountaineering accidents. Loss of footing (carelessness) accidents (274 total cases) were the highest type of fall during

the study period. The year 2018 had the most accidents overall. Falls in 2018 reached 23, distress had 72, attempted suicide reached 11, loss of footing (carelessness) had 100, and natural disasters had 25 cases. Personal disease was the second most common type of accident overall; it reached its highest frequency at 42 cases in 2019.

Table 4 shows the characteristics of mountain climbing accidents according to season. The accident types by season included 19 falls, 42 cases of personal disease, 66 distress accidents, and 23 natural disaster-related accidents in autumn. The highest number of accidents occurred in autumn and the highest number of attempted suicides was in winter with seven cases.

Tables 6–9 and Figure 2 show the characteristics of mountain climbing accidents depending on the weather. Data were analyzed with a cross-tabulation analysis. The results showed a statistical significance for temperature ($X^2= 63.40$, $p<.036$) and humidity ($X^2= 90.88$, $p<.006$). Specifically, the greatest number of fall accidents happened in the temperature range between 20 °C–24 °C (15 cases), followed by the 8 °C–10 °C temperature range (9 cases) and the 16 °C–20 °C range (9 cases). A similar number of cases of personal disease happened within the 20 °C~24 °C temperature range (15 cases), followed by the ranges 24 °C~28 °C (15 cases), 8 °C~12 °C (14 cases), and above 28 °C (14 cases). Distress accident was respectively high with the range of 20 °C~24 °C (36 cases) and 16 °C–20 °C (32 cases). For attempted suicide, it was highest for the temperature range of 8 °C~12 °C (5 cases) and loss of footing was the highest in the range of 20 °C~24 °C (49 cases). Lastly, natural disasters were consistently distributed in the temperature range above 20 °C.

In the case of the accident types by humidity, fall accident occurred the most with 50~55% humidity (15 cases). Followed by personal disease at 55~60% humidity (16 cases), and 60°C~65% humidity (14 cases). Distress accidents appeared at 45~50% humidity (29 cases), and 60~65% humidity (28 cases). Attempted suicide appeared at 45~65% humidity (15 cases) and it was highest at 50~55% humidity. Loss of footing was the highest at 60~65% humidity (47 cases). Lastly, natural disasters were the highest at 60~65% humidity (14 cases). Loss of footing happened the most in the 60~65% humidity range (47 cases). Lastly, natural disasters happened the most at 60~65% humidity (14 cases).

For the accident types according to cloud cover, the highest number of fall accidents happened with 10% cloud coverage (14 cases). Personal disease accidents were highest at 10% coverage (17 cases),

followed by an 80% coverage (16 cases). Distress accidents appeared with 10% coverage (36 cases), and at 80% (22 cases). Attempted suicide was the highest with 10% coverage (4 cases). Loss of footing was highest with 10% coverage (47 cases), and lastly, natural disasters were highest with 40% coverage (13 cases).

Lastly, the accident types according to wind show that fall accidents were most frequent with wind conditions of 6–8 km/h (25 cases). Personal disease was high under 6–8 km/h wind speeds (39 cases) and distress accidents were high in that same range (70 cases).

DISCUSSION

This study explored the relationship between hiking accidents and weather conditions. The results showed that the number of hikers was highest in 2020, even though data were collected only up to October of that year. It seems there has been an increase in the number of hikers, because “people are doing outdoor activities such as hiking because of COVID-19” (Holly, 2020). As the media and the news are spreading the word that COVID-19 is highly infectious indoors, people tend to prefer outdoor activities. In addition, the increase in hiking is common in South Korea, because the country has many mountainous areas conducive to this activity. However, as more people are hiking to avoid indoor activities, there are concerns about the spread of COVID-19 among hikers.

The hiking accidents that happened on Bukhansan Mountain were classified into six types. Mainly, falls, personal disease, distress, attempted suicide, loss of footing, and natural disasters. Notably, loss of footing (carelessness) counted for 40% of all the accidents with 274 cases. As a result of analyzing by season, all the accident types except suicides were concentrated in autumn, which was similar to the findings by Jong-deok Moon(2020) that claimed hiking accidents in national parks happen most frequently in October when the leaves change color and fall. In other words, the greatest number of accidents happened in autumn, the season with the highest number of visitors, but the number of accidents was lower in spring even though the weather conditions and the number of visitors were similar. Therefore, safety education and guidance should be provided to prevent hiking accidents and personal carelessness in autumn in particular. Additionally, attempted suicide was the most common in winter. There are studies underway to prove that hiking reduces negative psychological factors like stress, depression, and suicide (Sturm et al., 2012). However, there are

those that hike with an ulterior motive: to attempt suicide. Therefore, suicide-prevention signs or preventive measures are needed at the trailheads, on the course guide, near areas where attempted suicide is more common, and near secluded spots.

There are many studies about the relationship between weather and accidents, and they have shown that weather can cause car, railroad, and aviation accidents as well as fires (Malin, Norros, & Innamaa, 2019; Skorupski, 2015). Based on this correlation, the relationship between weather and hiking accidents are discussed in detail. First, in terms of the temperature, the highest number of accidents happened in the temperature range 20–24 °C and if expanded to include the 16–28 °C range it correlated with 44.3% of all the accidents. This result partially matches the result of other studies such as one that indicated gas accidents happen the most within the temperature range of 20–25 °C and car accidents within the 25–30 °C range. For this reason, management and incident response teams must be aware that many accidents happen within the temperature range of 16–28 °C and efforts should be made to post more information and notifications along the hiking course that inform hikers about risks in specific temperature ranges. The temperature and accidents appear in the U, J, and V forms and this study was similar to the J type. In other words, it can be identified that many hiking accidents happen when the temperature reaches an average annual temperature. This means that people are physically in a defensive state in low or high temperature in order to correspond to the external environment but once the temperature reaches an optimum level, then the physical defensive state weakens and this leads to unexpected accidents. Accordingly, this points out that prevention of hiking accidents should be more emphasized the more the temperature is suitable for hiking. Regarding humidity, accidents happened most frequently at a 60~65% humidity range and for cloud cover, accidents happened the most when there was 10% (clear) cloud cover. Regarding wind, accidents happened the most in the 6–8 km/h range. It appeared that the accidents with these weather characteristics were similar to the results for other accidents. For example, this result partially matched the research result of Kim and Lee (1990) for car accidents. In their study, accidents happened the most in the 25.1–30 °C range. It also was similar to the results of Heo and Lee(2010) on gas accidents, which were more common in the 20–25 °C range. In the research by Lee and Kim(2007) where the analysis was performed on fatal car accidents with humidity as

the independent variable, the result showed that days with a humidity range of 50–70% had the most fatalities from car accidents with 566 (46.4%) people. This was similar to the findings of this study. In summary, hiking accidents are common in the temperature range of 16–28 °C, a humidity range of 60~65%, and a wind range of 6–8 km/h. At the same time, these weather conditions are ideal for people interested in hiking.

In other words, campaigns or educational information should communicate that ideal weather carries the highest risk of hiking accidents. It should be publicly available and disseminated by the parks' management team. Moreover, the government should provide advisory information to the hikers through signs, course guides, and electronic displays installed in national parks. While hikers should always be careful about safety-related accidents, they should be even more cautious when they hike in specific environments under certain weather conditions. Considering the weather conditions, there is a high risk for hiking accidents to happen in normal environment although accidents tend to occur in bad weather conditions. Accidents can be reduced depending on how defensive people are about the external environment. However, in case of hiking, people recognize the weather and respond to it and people have low risk awareness about normal weather, so it leads to a higher risk of accidents than bad weather conditions. Therefore, we implied that accidents that appear in hiking can be different from previous accident types and these characteristics should be considered to provide information to the hikers. This study identified the relationship between hiking accident types and weather conditions. The study comes at a time when more people than ever are interested in hiking because of COVID-19 restrictions. However, this study has the following limitations. First, the weather conditions in South Korea were considered, so careful caution is needed to apply its weather environment to other countries for interpretation. Second, Bukhansan Mountain is located in a downtown region, which has an area of around 79.91 km² along with four distinct seasons that make it favorable for hiking. Accordingly, it must be distinguished from other mountain accidents with other intentions like climbing. Lastly, the accident types were categorized, but the details and severity of injuries could not be taken into consideration. In further studies, including a comparative study about weather for hikers and people experienced with accidents along with weather factors and accident hazard will establish an effective study for

the prevention of hiking accidents.

CONCLUSION

This study focused on presenting weather characteristics and hiking accidents at Bukhansan Mountain, which has the highest number of visitors per unit area. Since weather influences different accident types, it is a factor that must be considered in order to prevent hiking mishaps. Especially, it appeared that many loss of footing accidents happened because of falls or personal carelessness, so specific, target advisories about weather and accident risk should be provided in the park. Regarding the characteristics of weather-related accidents, many happened within the temperature range of 16–28 °C, a humidity of 60–65%, and winds of 6–8 km/h. We anticipate this information will provide a positive effect on park safety and hikers' safety by preventing accidents and providing guidance.

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Supplementary material Appendix i, (Table 1- 9 and Figure 1-2)

Table 1. Number of visitors to Bukhansan National Park

year month	2018	2019	2020	Total
January	153,176	204,949	243,610	601,735
February	160,960	195,516	244,075	600,551
March	250,528	254,682	427,418	932,628
April	249,296	251,683	449,068	950,047
May	329,787	294,873	382,807	1,007,467
June	324,754	286,591	343,279	954,624
July	290,771	221,600	324,956	837,327
August	238,382	295,788	224,089	758,259
September	321,271	262,595	334,201	918,067
October	341,846	347,185	420,910	1,109,941
November	257,107	310,162	-	567,269
December	202,242	215,779	-	418,021
Total	3,120,120	3,141,403	3,394,413	9,655,936

Table 2. Weather characteristics in 2018-2020

Year Weather	2018				2019				2020			
	N ¹	M ²	MO ³	MA ⁴	N	M	MO	MA	N	M	MO	MA
Temperature	259	15.46	23.70	33.10	221	14.77	25.00	31.60	206	15.94	13.10	30.20
Humidity	259	55.78	48.80	92.40	221	55.34	60.00	92.90	206	62.27	64.30	93.50
Cloud cover	259	4.07	0.00	10.00	221	4.57	0.00	9.80	206	4.72	0.00	10.00
Wind velocity	259	6.02	5.40	13.70	221	6.80	6.10	13.70	206	8.31	7.20	17.30
precipitation	259	1.54	0.00	96.50	221	1.19	0.00	62.30	206	1.49	0.00	61.00

Table 2. note: Factor description: ¹Number of accidents(N), ²Mean(M), ³Mode(MO), ⁴Maximum(Ma)

Table 3. Weather characteristics by season in 2018–2020.

Seasons Weather	Spring	Summer	Autumn	Winter
Temperature	7.66	23.88	19.97	2.09
Humidity	48.88	61.23	62.20	53.07
Cloud cover	4.01	5.24	4.22	4.09
Wind velocity	7.95	6.66	6.73	6.61
Precipitation	0.57	1.32	2.21	0.78

Table 4. Characteristics of hiking accidents by year for the 3 recent years

Year Accident	2018	2019	2020	Total
Fall accident	23	14	20	57
Personal disease	28	42	29	99
Distress accident	72	49	57	178
Attempted suicide	11	1	3	15
Loss of footing (carelessness)	100	91	83	274
Natural disaster	25	24	14	63

Table 5. Characteristics of hiking accidents by season

Seasons Accident	Spring	Summer	Autumn	Winter	Total
Fall accident	14	12	19	12	57
Personal disease	23	21	42	13	99
Distress accident	42	47	66	22	178
Attempted suicide	2	2	4	7	15
Loss of footing (carelessness)	54	79	91	50	274
Natural disaster	15	17	23	8	63

Table 6. Hiking accidents by accident types followed by the temperature

Temperature Accident	under - 4.0°C	-4.1~ 0.0°C	0.1 ~ 4°C	4.1 ~ 8°C	8.1~ 12°C	12.1 ~ 16°C	16.1 ~ 20°C	20.1 ~ 24°C	24.1 ~ 28°C	above 28.1 °C	X ²	p
Fall accident	2	1	7	2	9	7	9	15	4	1	63.40	.036
Personal disease	4	6	2	6	14	11	12	15	15	14		
Distress accident	6	8	13	16	15	23	32	36	20	9		
Attempted suicide	0	2	1	1	5	0	1	3	2	0		
Loss of footing (carelessness)	8	21	26	19	31	27	37	49	30	26		
Natural disaster	0	2	4	9	9	4	3	11	10	11		
Total	20	40	53	53	83	72	94	129	81	61		

Table 7. Hiking accidents by accident types followed by humidity

Humi dity Acciden t	0~ 25 .0	25. 1~ 30. 0	30.1~ 35.0	35.1~ 40.0	40.1~ 45.0	45.1~ 50.0	50.1~ 55.0	55.1~ 60.0	60.1~ 65.0	65.1~ 70.0	70.1~ 75.0	75.1~ 85.0	85.1~ 99.9	X ₂	p
Fall accident	0	1	1	3	5	5	15	6	8	7	2	4	0	90. 88	.0 06
Persona l disease	1	0	8	7	7	10	7	16	14	13	4	10	2		
Distress accident	1	4	4	14	13	29	19	16	28	22	19	7	2		
Attempt ed suicide	0	0	0	0	0	2	2	8	3	0	0	0	0		
Loss of footing (careles sness)	0	6	6	17	16	26	37	40	47	35	21	17	6		
Natural disaster	0	0	0	6	3	4	5	6	14	7	7	8	3		
Total	2	11	19	47	44	76	85	92	114	84	53	46	13		

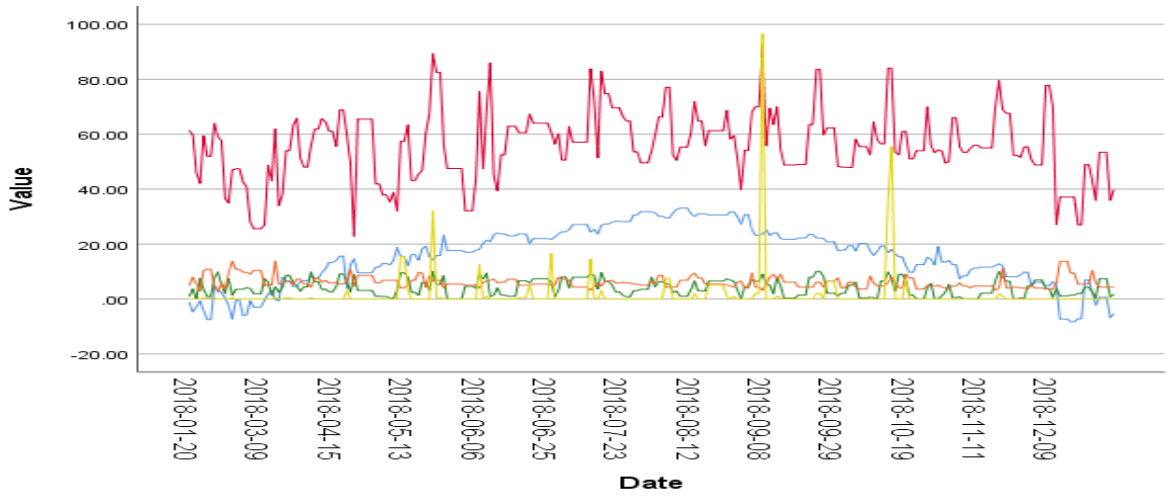
Table 8. Hiking accident by accident types followed by the cloud cover

Cloud cover Accident	10	20	30	40	50	60	70	80	90	100	χ^2	p
Fall accident	14	5	5	5	3	2	5	9	4	5	40.00	.683
Personal disease	17	9	5	11	7	12	14	16	6	2		
Distress accident	36	19	17	20	13	12	18	22	8	13		
Attempted suicide	4	0	1	2	1	2	2	2	1	0		
Loss of footing (carelessness)	47	22	40	31	24	23	24	33	14	16		
Natural disaster	7	2	3	13	6	7	8	7	5	5		
Total	125	57	71	82	54	58	71	89	38	41		

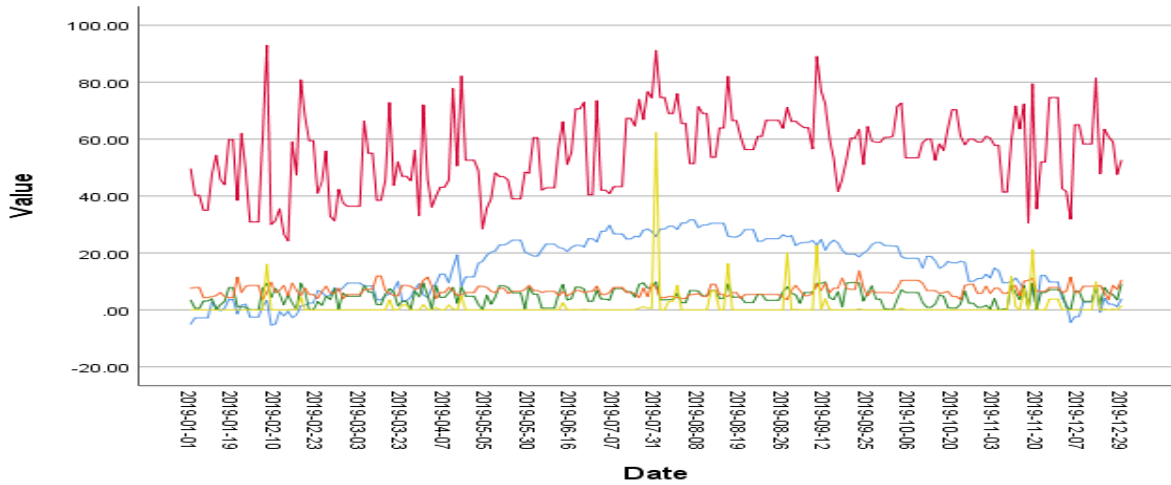
Table 9. Hiking accidents by accident types followed by the wind velocity

Wind velocity Accident	under 4(km/ h)	4.1~6.0(km /h)	6.1~8.0(km /h)	8.1~10.0(km /h)	10.1~12.0(k m/h)	12.1~14 .0 (km/h)	Above 14.1(km/ h)	χ^2	p
Fall accident	5	12	25	3	8	2	2	37.9 2	.15 2
Personal disease	3	31	39	16	8	2	0		
Distress accident	11	49	70	28	16	3	1		
Attempted suicide	4	4	4	1	1	1	0		
Loss of footing (carelessness)	25	84	93	42	23	6	1		
Natural disaster	2	21	24	12	3	0	1		
Total	50	201	255	102	59	14	5		

Figure 1. Accident climate characteristics according to year
 Accident climate characteristics in 2018



Accident climate characteristics in 2019



Accident climate characteristics in 2020

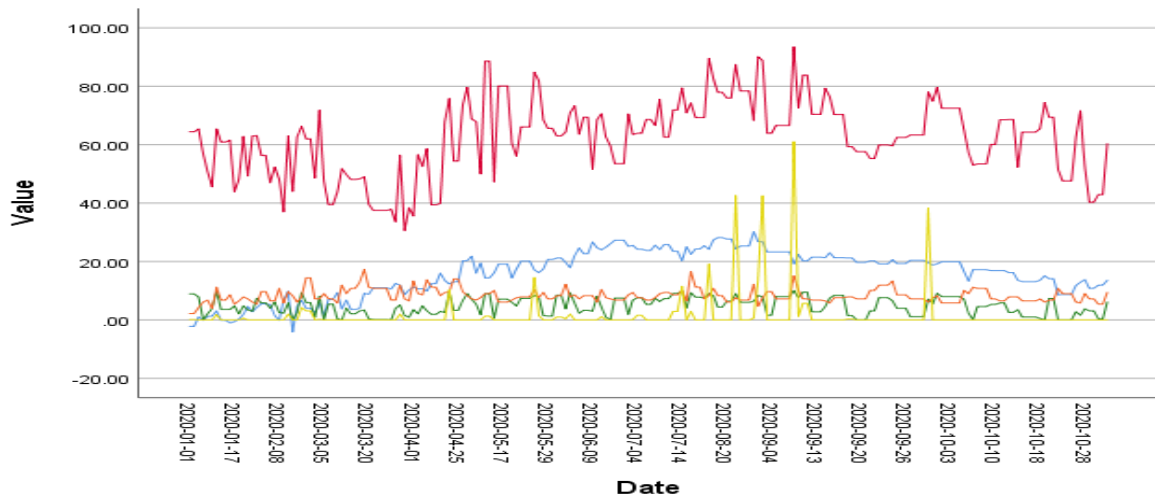


Figure 1. note: Temperature (blue line), Humidity (red line), Cloud cover (green line), Wind velocity (orange line), precipitation (yellow line)

Figure 2. Characteristics of hiking accidents in 2018–2020 according to Weather.

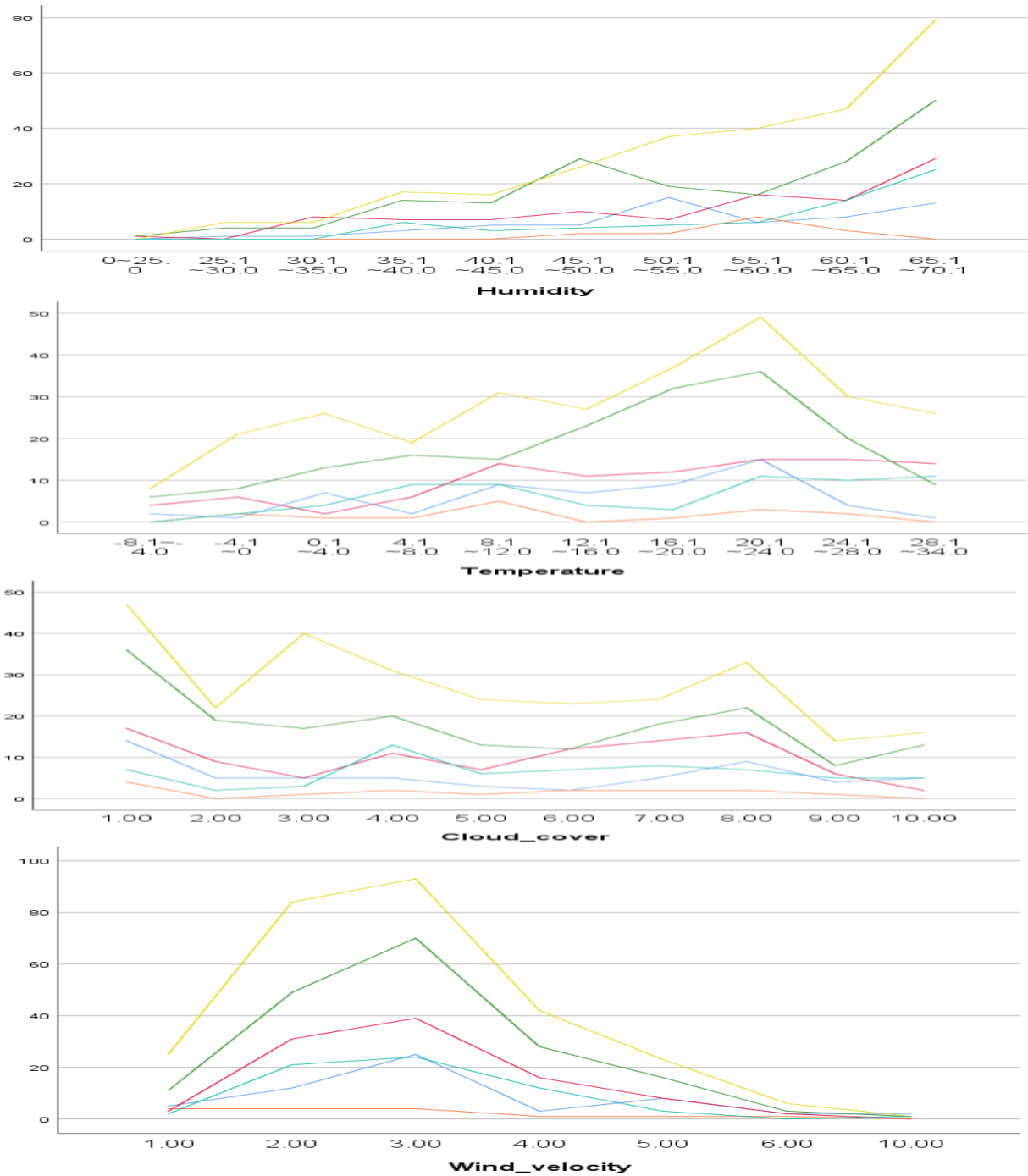


Figure 2. note: Fall accident (blue line), Personal disease (red line), Distress accident (green line), Attempted suicide (orange line), Loss of footing (yellow line), Natural disaster (jade line).