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森林遊樂區風險管理研究：

溪頭自然教育中心意外事件分析

Risk Management in Forest Recreation Destination: Incident Analysis of Xitou Nature Education Area

藍俊可

Jittakon Ramanpong

指導教授：余家斌 博士

Advisor: Chia-Pin Yu, Ph.D.

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森林遊樂區風險管理研究：溪頭自然教育中心意外事件分析

Risk Management in Forest Recreation Destination: Incident Analysis of Xitou Nature Education Area

本論文係藍俊可君（ D06625005 ）在國立臺灣大學森林環境暨資源學系、所完成之博士學位論文，於民國 110 年 9 月 7 日承下列考試委員審查通過及口試及格，特此證明

口試委員：

余家斌 （簽名）

（指導教授）
蔡明哲

吳治達

王俊杰

李曉昀

系主任、所長 曲芳華 （簽名）

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中文摘要

為了減少戶外遊憩風險並維護遊客的安全，管理單位可以從先前意外事件案例中學習，了解事件統計記錄、事故頻率或死亡人數等描述性統計數據，並進一步了解人為因素以及環境因素對於事件發生的影響。本研究以溪頭自然教育園區為研究地點，分析了人為因素和環境因素等潛在影響因素對所遊客意外事件的影響，可作為森林遊樂區風險管理規劃之用。

本論文採用回顧性分析，以了解 2012 年 7 月至 2018 年 6 月台灣溪頭自然教育中心（XNEA）發生的疾病和傷害事件。 276 例患者的傷病病例的流行病學分析結果， 56.2% 為女性，平均發病率呈下降趨勢，約為 0.024 例 / 1,000 人-日，即每 100,000 名遊客約 3 例病例。大部分病例發現於大學池、巨型觀景台、溪頭自然教育中心入口（二號入口）等著名旅遊景點。超過一半的患者 (55.4%) 有固有的健康狀況。最普遍的症狀是頭暈（47.8%）。大多數的病例發生在早晨和夏季。患者的平均年齡為 52 歲（範圍 2-93 歲）。老年遊客（≥60 歲）最容易出現健康問題。通過卡方檢驗，我們發現發生暈厥的男性多於女性。患有高血壓的遊客出現頭暈、呼吸問題和暈厥的風險更大。糖尿病患者容易虛弱。有心臟相關問題的人容易出現胸痛或胸悶。

除了對疾病病例的研究外，本論文還對傷害案例進行了研究，發現 2012 年 7 月至 2018 年 6 月期間記錄了 957 起傷害案例。超過一半的傷者（59.6%）為女性。受傷訪客的平均年齡約為 49 歲（範圍 1-92 歲）。他們中的大多數 (71.5%) 因滑倒、絆倒或從高處墜落而受傷。夏季月份和下午時間是受傷案件最頻繁的時期。分析的傷害率約為每年 0.090 例 / 1,000 人-日，或每 100,000 名訪客約 9 例傷害案例。從熱點圖來看，大部分的受傷案例都被發現在一些熱門的旅遊景點，如遊客中心、大學池和溪頭的入口處。與其他景點相比，這些景點海拔較低且相當平坦。天氣變項和遊客傷害風險的地形資訊已納入 Poisson 和負二項式回歸模型中。 Poisson 和負二項式回歸模型都證明了類似的發現，即每日遊客傷害率與關於平均氣溫、相對濕度和降雨條件的天氣共變量呈正相關。模型選擇標準和適配度表明，負二項式模型比 Poisson 回歸模型提供了更好的模擬。受傷率風險與平

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均氣溫、相對濕度和降雨條件的增加有關，發病率比 (IRR) 分別為 1.019、1.020 和 1.438。關於傷害率的地形變量與 Poisson 和負二項式回歸的關係表明，平均海拔和傷害發生地點的平均坡度對傷害率在統計上不顯著。

本論文的結果證實，過往病史對戶外參與者構成了固有風險，而這種在戶外休閒期間病發的關係證實了特定患者群體的風險更大。在森林中遭受的傷害與天氣因素有關，尤其是下雨。這些研究結果都為未來的事故預防計劃以及旅行者提供了具體的證據和資訊以正確地認識事故風險。

關鍵字：風險管理、森林遊憩、戶外安全、遊客事件、既往醫療狀況、GIS

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Abstract

To develop a proactive manner for visitor risk management, it is imperative for the outdoors organization to learn prior incident cases not only the descriptive statistics such as statistical records of incidents, frequency of accidents, or deaths but also the correlation analysis. Different from conventional incident reports, this dissertation analyzes the effect of potential contributing factors regarding human factors and environmental factors to the incident experienced.

This dissertation applied the retrospective analysis in order to provides the comprehension of incident cases both illness and injury encountered in Xitou Nature Education Area (XNEA) of Taiwan between July 2012 and June 2018. Epidemiologic analysis results of illness cases indicated of the 276 patients assessed, 56.2% were female with a decreasing trend of the average rate of about 0.024 per 1,000 person–days, or around 3 illness cases per 100,000 visitors. Most of the illness cases encountered were found to some of the famous tourist spots, such as the University Pond, Giant Scenic Platform and XNEA's entrances (Second Pass). More than half of ill participants (55.4%) had preexisting health conditions. The most general symptom was dizziness (47.8%). Most health-related cases took place in the morning and during summer period. The average age of ill participants was 52 years (range 2–93). Elderly visitors (≥60 years) were the most susceptible to illness. By using chi-square test, we found that more men than women encountered syncope. Participants with high blood pressure had a greater risk of experiencing dizziness, respiratory problems, and syncope. People with diabetes were susceptible to weakness. People with cardiac-related problem were vulnerable to chest pain or tightness in their chest.

doi:10.6342/NTU202103140

Apart from studying in illness cases, this dissertation also study injury cases and found that 957 injury cases were documented between July 2012 and June 2018. Over the half of injury patients (59.6%) were female. The average age of injured visitors was about 49 years (range 1−92 y). Most of them (71.5%) experienced an injury because of a slip, a trip, or a fall from a height. Summer months and afternoon time were the most frequent periods of injury cases. Injury rate analyzed was about 0.090 per 1,000 person−day a year of injury cases, or around 9 injury cases per 100,000 visitors. From the hot spot map, most of the injury cases were discovered to some of the popular tourist spots, such as the visitor center, University Pond, and XNEA's entrances. These spots are at lower altitudes and quite flat compared to other tourist spots. Weather variables and topographical information on visitor injury risks have been fitted in Poisson and negative binomial regression models. Both Poisson and negative binomial regression models demonstrated a similar finding that daily visitor injury rate was positively related to weather covariates regarding average air temperature, relative humidity, and rain condition. Model selection criteria and goodness−of−fit revealed that the negative binomial model provides the better fit than the Poisson regression model. Risk of injury rate was associated to an increase in average air temperature, relative humidity, and rain condition with the incidence rate ratio (IRR) at 1.019, 1.020, and 1.438, respectively. The relation of topographic variables on injury rate fitting in Poisson and negative binomial regression indicated that average elevation, and average slope of injury locations were statistically insignificant for injury rate.

The results of this dissertation confirmed that preexisting medical conditions establish an inherent risk in outdoor participants, and this relationship with the development of illness during outdoor recreation confirmed greater risks in specific

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patient groups. Injury experienced in forest was associated with weather factors particularly the occurrence of rain. All of these provides concrete evidence and information for future incident prevention programs as well as for the right perception of incident risk for future travelers.

Keywords: Risk management, forest recreation, outdoor safety, visitor incident, preexisting medical conditions, GIS

doi:10.6342/NTU202103140

Table of Contents

doi:10.6342/NTU202103140

doi:10.6342/NTU202103140

doi:10.6342/NTU202103140

List of Tables

doi:10.6342/NTU202103140

List of Figures

doi:10.6342/NTU202103140

doi:10.6342/NTU202103140

Chapter 1 Introduction

1.1 Introduction

With rapid urbanization and lifestyle change at present, people are spending more their lives in highly urbanized society and keeping themselves away from nature (Karjalainen et al., 2010; Kuenzi & McNeely, 2008; Nilsson et al., 2007; Yu & Hsieh, 2020) especially when the tourist sites are shut down as a result of crises, disasters, or pandemic isolated people from tourist destinations (Zenker & Kock, 2020). On the other hand, many people are still fascinated by natural environments and seeking memorable experiences (Haddock et al., 1993; Yu et al., 2019). The demand for terrestrial wildland recreation is rising on a global scale (Balmford et al., 2015). According to the first report into the worldwide scale of nature tourism, about eight billion tourists visits national parks and nature reserves every year (Balmford et al., 2015). Many reports from many countries highlighted the large number of tourists: there was 2.5 billion visits to the United State protected areas in 1996 (Eagles et al., 2000), more than 1 billion people visited China's National Parks in 2006 (Ma et al., 2009), and about 3.2-3.9 billion tourists visited British natural areas in 2010 (Sen et al., 2014). On the basis of natural wonders, healthy wildlife and nature, and authentic culture, tourism in the nature reserve is one of the most powerful sectors in the tourism industry worldwide (Leung et al., 2018). Being in nature to feel more connected to mountains, wildlife, forest, seashore, etc., is desirable for them (Kuenzi & McNeely, 2008).

Since connecting with nature or adventuring in the outdoors is perceived as a way to developing personal growth, skills, as well as healthy development across regions and generations, adventuring in the outdoors is considered a vital ingredient for

doi:10.6342/NTU202103140

modern life (Dickson & Gray, 2012). Many empirical studies demonstrate various physical and psychological health benefits from being in natural spaces or just viewing natural scenery (i.e. Maller et al., 2006). On the other hand, many articles also report the potential of encountering incidents in natural settings (Gstaettner et al., 2018). Visiting a natural area or participating in outdoor activities may induce people into at−risk conditions (Bauer, 2001; Gstaettner, Kobryn, et al., 2019; Kuenzi & McNeely, 2008). In 2002, for example, a female hiker who had a preexisting heart condition was found without vital signs near active lava flows at Hawaii Volcanoes National Park. Her body had contact burns from lava and the exposure to volcanic fumes was determined as the cause of death (Heggie & Heggie, 2012). It appears that risk in outdoor recreation activities not only involving with the potential to gain something of value but also the opportunity to lose something at the same time (Dickson & Gray, 2012; Haddock, 2013; Haddock et al., 1993; Meier et al., 1987). Therefore, taking a trip to natural areas is at risk of having an incident or dying in the worst scenario, and also the opportunity to explore the wondrous world and learn to live with the risks. Unlike the tourism in urban or city area, participating in outdoor recreation involves with many challenges. These challenges include a wide range of activities in austere, remote, and dangerous environments which also inherent diversity of challenges for prevention and planning practices of the recreation site (Alexander et al., 2016). Therefore, dealing with outdoor risk is a crucial component of nature-based tourism management (Eagles et al., 2002).

In terms of outdoor recreation practitioners, potential injuries, and illnesses that arise during various wilderness experiences are some of their responsibility (Angert & Schaff, 2010), and visitors also expect outdoor managers to limit those risks to acceptable levels (Haddock, 2013). Annually, many visitors suffer from injuries, and

doi:10.6342/NTU202103140

mortalities in wilderness areas all around the world (Gstaettner, Kobryn, et al., 2019). As greater people engage in outdoor, and wilderness activities in more severe and remote regions, there will be an increase in accidents, injuries, and illnesses in these areas (Heggie & Heggie, 2004). Consequently, the loss or incident of a tourist may be followed by numerous lawsuits, and expensive litigations (Eagles et al., 2002) as well as damage to the destination's reputation (Dickson & Gray, 2012). Defending lawsuits is particularly costly, and time intensive (Dickson & Gray, 2012; Spengler & Hronek, 2011). The increasing number of lawsuits corresponds to the increasing number of tourists and highlights the need for risk assessment, and research in outdoor recreational site management (Attarian, 2001; Brown, 1998). In many countries such as the United States, United Kingdom, and Australia, minimizing risk at recreational sites is compulsory and regulated by legislation (e.g., (Dickson & Gray, 2012; Keirle, 2002; Rickard, 2014b)). Therefore, exploring nature and wilderness areas inevitable entails risks that may threaten visitor's health, safety, and life, and then expose tourism businesses to liability (Kuenzi & McNeely, 2008). The duties of risk managers are thus to highlight the responsibility of users and to reduce legal exposure at the same time (Keirle, 2002).

Managing risks to ensure visitor health and safety and maximize their learning experience is regarded as an obligation of all types of outdoor recreation and tourism sites (Keirle, 2002; Spengler & Hronek, 2011). Nevertheless, achieving these goals is a complicated process (Brown, 1998) since risk involves the intricate interrelationships between humans and between humans and nature (Rayner, 1987). To help site managers in risk and safety management, including effective decision-making, many risk management models have been proposed (Brown, 1998; Spengler & Hronek, 2011).

doi:10.6342/NTU202103140

Visitor risk management provides a great contribution to outdoor recreation management (Department of Conservation and Land Management, 1998). Visitor risk management's concept requires outdoor recreation agencies to care for visitor safety whereas the benefits from the outdoor experience of visitors are still maintained (Rickard, 2014b). Also, visitor risk management is defined as the systematic approach of identification, analysis, and control of the wide array of visitor risks that threaten the ability of an organization to reach its goals. (Department of Conservation and Land Management, 1998; Eagles et al., 2002). Accordingly, enabling the desired experience of risk-taking in outdoor pursuits is required to learn from prior incidents in an effort to select the suitable control measures ensuring the ultimate goal of recreation experience for participants based on enhanced comprehension.

To obtain essential data with which to inform risk management plans, analyzing past events is imperative (Dickson & Gray, 2012; Spengler & Hronek, 2011). The analyzing process must consider the interactions of the causal factors associated with incident risk in outdoor activities regarding people (e.g. age, health, and fitness), equipment (e.g. clothing, equipment, and shoes), and environment (e.g. topography, infrastructure, and weather) that may differ in space and time (Brown, 1998; Haddock, 2013; Haddock et al., 1993). Incident analysis based on prior experience not only enables practitioners to comprehend the effect of circumstances at the time of an incident but also provides clues regarding risk's contributing factors (Dickson & Gray, 2012). This dissertation focused on risk identification and evaluation that can provide accurate and fundamental data for a fully understanding of real incidents that have occurred, the likelihood of incidents, and factors that contributed to particular incidents.

doi:10.6342/NTU202103140

From a risk management's point of view, risk identification and evaluation are the principal measures that rely on prior experience and include recognizing potential groups as well as determining an acceptable level of risk for participants (Barton, 2007; Ewert, 1984; Spengler & Hronek, 2011). However, removing all risks from outdoor recreation is unrealistic (Dickson & Gray, 2012; Eagles et al., 2002). Thus, sharing responsibility with relevant parties is recommended. In the wilderness tourism context, the management of incident risk is a shared responsibility between visitors and sites managers (Gstaettner et al., 2020; Gstaettner, Lee, et al., 2019; Jeuring & Becken, 2013; McDonald, 2003) together with tourism operators (Eagles et al., 2002). Managers should understand visitor characteristics that may lead to incidents and communicate risk information to travelers, who then must assume responsibility for recognizing the inherent risk and their personal well-being (Department of Conservation and Land Management, 1998; Dickson & Gray, 2012; Eagles et al., 2002; Grant et al., 1996; Rickard, 2014b). Visitors are implied to aware of their own risk that may encounter within the environment (Gstaettner, Lee, et al., 2019; McDonald, 2003; Rickard, 2014b) and adhere to warnings and safety instructions (Gstaettner et al., 2020) whereas the forest recreation practitioners are on duty to provide not just a reactive administration such as search and rescue operation but also proactive risk management practice such as interpretation of all foreseeable incidents (Dickson & Gray, 2012). However, tourists typically have a misconception about safety in the real environment. They are prone to see their surrounding environment to be safer than they really are (Heggie & Heggie, 2004; Rickard & Newman, 2014) and do not realize the inherent risks that can trigger incidents both illnesses and physical injuries (i.e. Adam, 2015; Heggie & Heggie, 2004; Rickard, 2014a). Thus, the comprehension of real risks of illness and injury inherited in

doi:10.6342/NTU202103140

outdoor recreation activities is essential, so tourists can have a sound understanding of risky situations.

One major area that really mattered for outdoor recreation risk management and focused in this dissertation research is population concerns. Outdoor practitioners need to know visitor characteristics that may lead to incidents and express those risk information to visitors, who then must assume responsibility for recognizing the inherent risk and their personal safety (Department of Conservation and Land Management, 1998; Dickson & Gray, 2012; Eagles et al., 2002; Grant et al., 1996; Rickard, 2014b). All tourists must be self-reliant when participating in an outdoor activity and know their own limitations, including physical abilities, to have a safe and satisfying excursion (Haddock, 2013). Physical impairments, neurological disorders, age, and stage of disease all affect outdoor recreation participant's welfare (Skaros, 1998). Visitors who have preexisting medical conditions or health concerns are considered unstable, and their health is at risk of getting worse during a trip (Greuters et al., 2009; Schutz et al., 2014). For this reason, wilderness medical physicians strongly recommend all travelers to be in good health before embarking on wilderness travel (Auerbach, 2015b). This is not to suggest that wilderness travelers who have chronic illnesses or preexisting medical conditions should avoid wilderness expedition; however, they should aware of their limitations, as well as medical histories, before engaging in a wilderness excursion and reasonably select their own level of engagement (Auerbach, 2015b; Grant et al., 1996; Haddock, 2013). Visitors should to aware that their vulnerability in an individual's health status related to age, gender, and physical impairment is a risk factor in outdoor recreation engagement that contributes to incidents (Brandenburg & Locke, 2017; Gstaettner et al., 2018). For example, people

doi:10.6342/NTU202103140

with a history of medical conditions, such as cardiac-related problems, diabetes mellitus, and respiratory problems, can present symptoms during an outdoor activity even though the conditions are well controlled (Skaros, 1998).

Many reports have shown instances of illnesses encountered in recreation sites (e.g., Forrester & Holstege, 2009; Heggie & Heggie, 2009; McIntosh et al., 2007; Spano et al., 2018; Stella-Watts et al., 2012). Among these studies, few have traced whether visitor's medical conditions are connected with the medical problems encountered; for example, senior travelers are more likely to experience an illness than other groups, and this is associated with preexisting medical conditions being exacerbated in natural regions (e.g. Keyes et al., 2016; Peitzsch et al., 2020). In order to establish effective risk management strategies, further study should assess vulnerable conditions and the contributing factors that lead to illness incidents experienced among participants (Haegeli & Pröbstl-Haider, 2016). Outdoor recreation practitioners should therefore first consider visitor's health conditions in connection with their preexisting health conditions for visitor risk management.

Another challenging area of visitor risk identification and evaluation that this dissertation aims to explore is how environmental conditions influence visitors' risk. Specifically, environmental condition is really important issues for forest practitioners toward the application of incident prevention programs. Wilderness tourism corresponding to different environmental features such as elevation, terrain, and climate encompasses a wide array of risks (Bauer, 2001; Tuler & Golding, 2002). The hazards from outdoor recreations incorporate many risk sources such as steep and rocky terrain (e.g., Taubenböck et al., 2016; Wang et al., 2009) wildlife (e.g., Cherry et al., 2018; Conrad & Balison, 1994; Sakals et al., 2010), or severe weather (Jeuring & Becken,

doi:10.6342/NTU202103140

2013). Weather, for example, is an external factor that people cannot control or change. Also, understanding of climate condition is necessary for individuals to respond and prepare for safer trips (Dickson & Gray, 2012; Gilchrest, 1998; Jeuring & Becken, 2013).

Although the outdoor environment concerning topography, or weather conditions, cannot be controlled or removed by the operator but risks in outdoor recreation can be managed in order to keep a degree of realism in a natural context along with an outdoor recreationist's preference (Bentley et al., 2004). Therefore, improving the understanding of tourists and site managers in uncertainties from environmental factors is a need in an aspect of visitor risk management from an outdoors perspective (Dickson & Gray, 2012). A clearer picture of factors resulting in incident scenarios would be assisted in establishing effective incident prevention strategies (Heggie, 2006b). In greater depth, environmental factors regarding ambient temperature, relative humidity, rain condition, elevation, and slope are considered in this dissertation.

Finally, moving further from the descriptive explanation of incidents to etiological analysis is imperative for understanding to whom, in what circumstances, and how illnesses and injuries take place in the wilderness context and then to introduce the effective incident prevention strategies (Shanmugam & Maffulli, 2008). This research advances the traditional incident report by identifying to whom, in which conditions incidents have taken place as well as the effect of possible contributing factors based on evidence from past incidents encountered. The Xitou Nature Education Area (XNEA) was chosen as our study area by virtue of a rising concern of visitor safety in the XNEA, one of the most famous forest recreation destinations in Taiwan.

doi:10.6342/NTU202103140

The XNEA management team expects to have a better understanding of incident victims' profiles and potential incident risk factors for future risk management planning and reducing incidents in the future. A rising need for providing user's health and safety was proposed to XNEA's management team. Moreover, the records of past incidents experienced in XNEA were well documented. Therefore, the data availability was another aspect that has been taken into account.

1.2 Objectives and significance of the research

Regarding visitor risk management concept, this dissertation attends to fulfill the knowledge gap of the incident report and visitor risk management in nature tourism in Taiwan as well as supporting organization decision making in reducing future incidents. This research seeks to get together available evidence on illnesses and injuries encountered and explores associations of incident contributing factors. To do so, the objectives of this research are: (1) to report the possible incidents encountered in the Xitou Nature Education Area (XNEA), (2) to examine the relationship between visitor's preexisting medical conditions and illnesses encountered in XNEA, (3) to establish the relationship between injuries experienced by visitors and environmental condition factors including weather factors and topographic variables (4) to identify high-risk groups and high-risk environmental condition to determine which visitor group and in which circumstance to target to increase risk awareness and to support more practical knowledge to site managers in developing incident prevention programs.

Practically, this dissertation offers several benefits to society. First, the epidemiology of injuries and illnesses provides an overview of spatial incidents, which can help outdoor organizations in preparation for future search-and-rescue operations.

doi:10.6342/NTU202103140

Second, tourists and outdoor recreationists alike can learn the appropriate perception of incident risk and its contributing factors. Third, based on our research finding models, organizations can design or create proactive risk management strategies more effectively, which can help them to predict the risk of tourists' injuries from environmental conditions and estimate the risk of tourists' illnesses from human factors as well as to communicate to tourists the necessary preparation for engaging in outdoor activities. Fourth, providing more information, especially information based on scientific findings and not merely providing statistics, from this research may increase public awareness that can help to limit the exposure to liability and reputation vulnerabilities for tourism organizations. However, all these societal impacts have the same goal, to ensure the safety of tourists and the sustainability of the destinations.

doi:10.6342/NTU202103140

Chapter 2 Literature review

2.1 Outdoors risk

2.1.1 Nature of outdoor risk

Uncertainty and risk are integral parts of human experience. Throughout human life, risk-taking is unavoidable and because of that we can learn new things, growth and knowing ourselves better. As time goes on, human can develop their skills, social, physical, and psychological function through the taking of risks. While there are a vast array of risks undertaken to various activities by people in everyday life, outdoor activities found in natural areas always expose travelers to some degree of uncertainty and hazard that is difficult to separate (Heggie & Heggie, 2004). It is clear that the level of risk inherited in outdoor adventures plays an important role in outdoor recreation experience (Dingwall et al., 1989).

Recreating in outdoor is continuously gaining attention with the growing number of tourists (Balmford et al., 2015) and economic benefits involved (Geffroy et al., 2015). In the meantime, health and safety concerns are also influencing traveler's destination selection (Bentley & Page, 2001). Even though the risk is always in every outdoor activity but engaging in outdoor recreation also provides a variety of benefits to participants such as increased self-esteem, increased self-confidence, the exhilaration of overcoming or facing challenges, and a sense of achievement and wellbeing (Haddock et al., 1993). Taking a risk in an outdoor environment is a testing ground for participants to discover something new and master over the environment. However, as every coin has two sides, exploring nature and wilderness areas inevitably entails some risks that

doi:10.6342/NTU202103140

may threaten tourist health, safety, life, and the financial liabilities of the tourism business (Kuenzi & McNeely, 2008).

The term *risk* is widely referred to as the potential to lose something (Eagles et al., 2002; Meier et al., 1987). Risk can be interpreted from the likelihood that a certain hazard will cause harm that is influenced by the frequency of exposure and the severity of the hazard. In this sense, risk can be expressed qualitatively and quantitatively (Barton, 2007). A loss or damage is commonly thought of in terms of physical sickness. However, the loss may be involved with mental, social, financial, and public relations of an organization or its staff (Province of British Columbia, 2003). On the other hand, the major reason for people to take a risk is that they may gain something of value (Dickson & Gray, 2012; Haddock et al., 1993). The motivation to potentially gain something of value integrates good health, growing confidence, improving self-esteem, the challenge of an adventure, and fun (Haddock, 2013). Therefore, risk incorporates situations where one of the potential consequences is expected to be negative while the other is expected to be positive or more desirable (Adam, 2015). In sum, risk is acknowledged as a meaningful component of the outdoor experience dimension and conceptualized into two perspectives. First, it is a detrimental possibility of experiencing a negative consequence and something to be avoided. Second, it is a positive opportunity to get benefits and something to be desired in certain situations (Gstaettner et al., 2018). In previous studies, many outdoor risk factors were emphasized and described the negative effect in nature-based tourism (Table 2.1).

doi:10.6342/NTU202103140

Table 2.1 Contributing factor of negative effect in nature-based tourism

Risk factors	Studies
People	
Age, gender	Williamson et al. (2012); McCool et al. (2009); Parkin & Morris (2005)
Lack of knowledge/experience	Bentley et al. (2006); Ballantyne et al. (2005); Newsome et al. (2004)
Lack of skills/fitness	Buckley (2010); Bentley et al. (2008); Hartmann (2006)
Environment	
Poor weather condition	Jeuring & Becken (2013); Bentley et al. (2010); Bentley & Page (2008)
Extreme heat/cold	Houge Mackenzie & Kerr (2012); Bentley et al. (2010); Uriely et al. (2002)
Dangerous animals	Cherry et al. (2018); Bentley et al (2010); Conrad & Balison (1994)
Management	
Lack of information/service	Jeuring & Becken (2013); Houge Mackenzie & Kerr (2012); Uriely (2002)
Lack of safety systems	Bentley et al. (2010); Bentley & Page (2008); Bentley et al. (2004)
Poor communication/decision-making	Bentley et al. (2010); Buckley (2010); Bentley & Page (2008)

(Source: modified from Gstaettner et al., (2018))

Visitor risks or risks experienced by participants in nature-based recreation activities can vary from the risk of trip cancellation because of severe environmental conditions such as extreme weather or unpassable route to the risk of injury or death because of human error or equipment failure (Haegeli & Pröbstl-Haider, 2016). Those elements that lead to the likelihood of an incident occurring are risk factors categorized

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into three groups: people, equipment, and environment (Haddock et al., 1993; Province of British Columbia, 2003). When these three factors combine whereas people are still participating in an activity, they are at the greatest potential for risk of incident (Haddock et al., 1993; Province of British Columbia, 2003).

Risk is strongly connected to the relationship between humans and nature (Gstaettner et al., 2018). When the terms risk and outdoor recreation are integrated, this term encompasses all activities in outdoor pursuits that are carried out in an outdoor environment whether on land, air, water, snow, or ice (Meier et al., 1987). Various instances of activities associated with these definitions include mountain climbing, scuba diving, caving, hot air ballooning, skiing, camping, snowmobiling, gliding, etc. (Meier et al., 1987). Involvement in these risk activities commonly uses synonymously with many terms such as rugged recreation, outdoor-adventure program, high-adventure programming, challenge programs, and outdoor pursuits (Meier et al., 1987).

Of course, outdoor adventure holds a powerful attraction for people to experience a degree of risk and uncertainty which can fulfill participant’s desire for memorable, joyful experiences and feelings (Haddock et al., 1993). The motivation to gain something of value from risk-taking in adventure-based outdoor activities is a constituting part of numerous education, recreation, adventure tourism, and community programmers (Haddock, 2013). Meanwhile, society expects outdoor managers to limit risks to acceptable levels for them (Haddock, 2013). In deciding the acceptable degree of risk, the odds of positive outcomes, and the consequences of failure should be defined which the acceptable risk is different among individuals (Gilchrest, 1998).

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Risk in the outdoor recreation context can be defined into three possible levels which are absolute risk, residual risk, and perceived risk (Haddock, 2013). Firstly, absolute risk is the maximum risk possessed in a situation that has no safety control measures present (Haddock, 2013; Haddock et al., 1993). Secondly, the residual risk is the amount of risk present after the absolute risk has been modified by safety control measures (Haddock, 2013). Lastly, perceived risk is an individual's subjective evaluation of the residual risk which normally varies from person to person and can be ranged from absolute risk to completely no risk (Haddock, 2013). The variations between people may be influenced by their confidence level, experience, fatigue, equipment familiarity, awareness of their own limitations, understanding of situation, anxiety and so on which these factors can cause some problems when the risk that people perceiving is different from the residual risk (Haddock, 2013).

2.1.2 Related terms of risk

This section explores the meaning and scope of some related terms of risk. Throughout the remainder of this dissertation, the related terms of risk will be referred to as the meaning in this section.

The first word that needs to be explored is an *accident* which sometimes is interchangeably used with the term *incident*. However, there are some points noted by Haddock (2013) about using this word. Haddock (2013) notes that an accident was an unplanned and unforeseen circumstance whereas many of the injuries experienced in outdoor activities could be foreseen and then prevented. Also, some organizations are trying to stop using the term accident to describe an unfavorable event. Haddock (2013) also mentions that the police, search and rescue, and government agencies used the term

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incident instead of the term accident to describe any event requesting intervention. Therefore, an accident is an unexpected and uncontrollable circumstance that results in damage to people (Dickson & Gray, 2012). The damage of accident is not only limited to injury but also involves both injury and illness whether mental or physical harm (Haddock et al., 1993). Haddock (1993) also clarifies that accident also involves damage to property and loss to process (disruption to the program). As discussed previously, an incident is an alternative term that many organizations are shifting to use instead of an accident. However, both terms are all involved harm to people (fatality, injury, and illness), damage to property, loss to process, and a close call or near miss (high potential for harm) (Haddock, 2013). Moreover, an incident may also include no injury, harm, or damage events that had the potential to do so (Dickson & Gray, 2012)(Dickson & Gray, 2012). To sum, an incident is foreseeable and preventable whereas an accident is unexpected, uncontrollable, unplanned, and unpredictable.

The next term is a *hazard*. The term Hazard or causal factor is anything with the potential to cause harm or damage (Barton, 2007). This means a hazard is a contributing factor to incidents (Haddock, 2013). Moreover, a hazard can be a situation or condition with the potential to cause harm (Department of Conservation and Land Management, 1998). Examples of hazards involve falls from height, drowning, technical fault, falling objects, lightning and so forth (Barton, 2007). Hence, we can simply say that a hazard is the origin of accidents and/or incidents. As mentioned by Haddock (1993) that injuries and illness arise from accidents but not all accidents introduce injury or illness.

Another term is *injury*. Schuh-Renner (2019) defined an injury as tissue damage because of energy passing through humans whether by intention or unintentional force. Specifically, intentional forces may be assaults, homicides, or suicides (Dickson & Gray,

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2012). However, this definition proposed by Schuh-Renner (2019) only covers the transferring of external energy to the body. In some cases, people can experience an injury from transferring energy out of their body such as in cold environments. A more relevant definition was developed by Dr. William Haddon Jr. in the late 1960s known as Haddon Matrix (Heggie, 2006b) which defined the transferring of energy to a human body in an amount exceeding or below the threshold for tissue damage (Heggie, 2006b). These energies include kinetic energy, heat, radiation, chemical energy, and electricity (Heggie, 2006b). More specifically, an injury includes any bodily hurt or pain but may not result in damage (Genik & McMurtry, 2019).

Finally, an *illness* is expressed as an interruption, cessation, or disorder of functions, system, or organs and represents a medical problem (McIntosh et al., 2007). Some examples of illnesses have been reported such as gastrointestinal illnesses (McIntosh et al., 2007), altitude sickness (Koirala et al., 2018), headaches (Chan et al., 2016), dehydration (Heggie & Heggie, 2012), respiratory irritation (Heggie & Heggie, 2012), asthma attack (Kogut & Rodewald, 1994) and cardiac distress (Martínez-Caballero & Sierra Quintana, 2019).

2.2 Visitor risk management

2.2.1 Principles of visitor risk management

It is clear that outdoor risk is present in outdoor activities involved both positive and negative outcomes but how to maintain the desirable benefits of taking risks while the potential damages are kept at an acceptable level is still a challenge placed on site managers. Controlling risks to ensure visitor health and safety and maximize their learning experience is regarded as a responsibility of all types of outdoor recreation and

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tourism (Keirle, 2002; Spengler & Hronek, 2011). Mostly, it is unfeasible to completely separate all hazards and risks from outdoor recreation experience (Clarke, 1998; Grant et al., 1996; Haddock, 2013). The more extreme the activity, the higher the chance for serious incidents. However, adding some measures can decrease the likelihood of adverse events (Skaros, 1998). Also, the positive benefits of taking activities need to be considered in a triangle, and a very different dynamic in respect to benefits, hazards, and control measures (Haddock, 2013) (see figure 2.1).

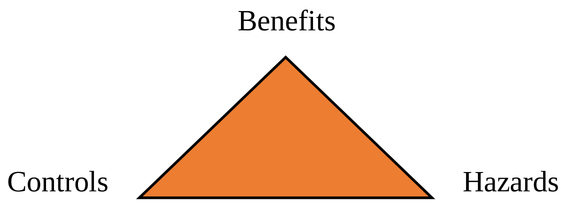

Figure 2.1 Controls, benefits, and hazards (source: (Haddock, 2013))

Being able to figure out or identify potential incidents of both injury and illness is the fundamental step for management of injury and illness in wilderness areas (Alexander et al., 2016). The U.S. National Park Service, for example, has currently paid more attention to the field of injury epidemiology to gain insight and better control of incidents in national parks (Heggie, 2006b). The park personnel who working on park user incidents will complete an Emergency Medical System Report at the scene of the incident providing the information of nature and environment, the basic medical and demographic information respecting the incident, and a summary of their responses to the incident before transferring the data to be a case incident report (Heggie, 2006b).

The epidemiological approach implies that incidents do not occur solely by chance. All of the incidents are the negative consequence of a series of activities taken

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in place and time sequence instead of a specific moment. As an example shared by Heggie (2006b) that in 1998, a Japanese family was rescued after their missing into a lava field at Hawaii Volcanoes National Park. This family hiked about 4-6 kilometers over uneven basaltic terrain in an effort to see the magma flow while wearing tennis shoes and sandals and bringing only a liter of water among them. Their ignorance in warning signs and unawareness of possible risks exposed them to severe dehydration while they were wandering in a confused state at the time of rescuing. Obviously, an incident intertwines with a range of risk factors.

Recently, Gstaettner et al. (2018) have done a systematic review generating a summary of risk factors contributing to incidents classified into three major groups including individual, environment, and management factor whereas Dickson & Gray, (2012), Haddock (2013), and the Province of British Columbia (2003) have proposed people, equipment, and environment are the main contributing factors of incidents occurring in outdoor programs. Specifically, Dickson & Gray (2012) separated the management factor into three pillars of risk management as a whole-of-organization approach regarding philosophy, policy, and practice which were based on social and political context such as norms, culture, laws, history, expectations, personal, organizational and collective experiences. In respect to Dickson and Gray (2012), Gstaettner et al. (2018), Haddock (2013), and the Province of British Columbia (2003), factors that contribute to the risk of incidents have been summarized in Table 2.2.

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Table 2.2 Risk factors potentially contributing to incidents

People	Equipment	Environment
• Age • Gender • Group size • Cultural background • Lack of abilities (e.g., skills/fitness/health) • Attitudes (e.g., lack of self-responsibility/lack of situational awareness, ignoring safety warnings/instructions)	• Clothing (e.g., lack of suitable clothing) • Use of safety equipment • Adequacy of safety equipment used • Communication systems used	• Weather (e.g., fast changing/poor weather condition) • Extreme heat/cold • Specific hazardous geographical condition (e.g., unstable terrain, tidal currents, rips, rough water, submerged) • Flora (e.g., poisonous plants) • Fauna (e.g., dangerous animals)

(Source: modified from Gstaettner et al, (2018); Province of British Columbia, (2003)

The term "whole-of-organization" in the approach to risk management expressed by Dickson and Gray (2012) emphasizes that risk management is the shared responsibility of everyone in an organization not only the risk manager or the risk and safety committee but also clients and participants. As noted by Gstaettner et al. (2018) that individual risk perceptions are developed by internal information regarding prior experience or knowledge learned from a certain hazard, condition, other people, and information available to a particular hazard such as warning signs. In this vein, the responsibility for visitor safety requires park management agencies to offer reasonably safety controls for park visitors whereas visitors also need to prepare themselves before taking the trip and adhere to warnings and safety messages onsite (Gstaettner et al.,

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2020). Thus, responsibility-sharing in the context of park and recreation is a shared obligation by site managers and visitors which both parties are required to comply with all reasonable measures to control the likelihood of incidents (McDonald, 2003).

However, outdoor participants tend to ignore risks and focus more on benefit outcomes (Gstaettner et al., 2017). Outdoor adventures mostly want to experience a sense of adventure without being injured and put the responsibility to outdoor managers to protect them from harm (Haddock, 2013). This places the emphasis on the effective visitor risk management approach in natural settings. Various studies about personal risk in outdoor recreation and tourism have been conducted in many activities providing the record of incidents and where the incidents occurred (Gstaettner et al., 2018). Research in this area aims to gain a better knowledge of the risk that took place in these activities and apply this understanding to effective programs informing choices to recreationists when attending their activities (Haegeli & Pröbstl-Haider, 2016). Therefore, visitor risk management is an information-driven approach for outdoor organizations in confirming reasonable risks in outdoor activities for outdoor practitioners.

2.2.2 Importance of visitor risk management

It goes without saying that some level of risk exists in all outdoor pursuits and dealing with the risk is a vital concern of park tourism management (Eagles et al., 2002; McIntosh et al., 2007). Park agencies are on duty to care for alarming potential incidents to visitors (Department of Conservation and Land Management, 1998). While risks are everywhere and every time, avoiding the risk is not recommended for outdoor recreationists. In doing so recreationists will not get the benefits of risk-taking such as

doi:10.6342/NTU202103140

gaining, growing, and learning some experiences. Therefore, participating in the activities with some degree of uncertainty under the risk management approach can maximize the potential positive effects and minimize the potential negative outcomes simultaneously (Clarke, 1998; Dickson & Gray, 2012; Ewert, 1984; Skaros, 1998).

Risk holds some degree of uncertainty but risk management encompasses foresight and control. Foresight is a proactive technique that possibly reduces the level of risk while the control measure is a thoughtful action an organization uses to reduce the likelihood of a risk and limit its negative outcomes (Eagles et al., 2002). Risk management is a science for an organization that applies to remain competitive and enabling them to deliver the desired experience to the users (Bentley & Page, 2008). Even though a medical emergency possibly occurs but having well-prepared management of activities will increase the chance all participants will have a safe and enjoyable trip (Skaros, 1998). Outdoor organizations are obligated to identify potential contributing factors and develop strategies and effective management measures that attempt to reduce or eliminate the potential of loss (Grant et al., 1996). To comprehensively understand and effectively manage the risk, accurate and reliable data that may be recorded over the years is important. These data include the frequency of incident, the circumstance at the time of the incident, the contributing factors to the incident, and the factors that mitigate or worsen the incident severity (Dickson & Gray, 2012).

As discussed in the previous section, risk management is the responsibility of every party in an agency. Another crucial characteristic of risk management is flexibility. Dickson & Gray (2012) emphasized that risk management is not a “one size fits all” procedure. In fact, risk management needs to be adjusted suitably with

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alteration in people, places, programs, communities, societies, and environments. Specifically, all stakeholders both internal and external party play a role in an iterative process of risk management (Dickson & Gray, 2012). In this regard, visitor risk management maintains the ability of an organization to attain its goals by applying the systematic identification, analysis, and control measures of visitor risks (Eagles et al., 2002).

A duty in response to visitor's safety, prevent incidents in natural recreational settings is also imposed by legislation (Haddock, 2013; McDonald, 2003). Failing on a duty of care to visitors may lead to liability arising from general law claims of negligence (McDonald, 2003). Litigation because of negligence is costly and time-consuming for most organizations (Dickson & Gray, 2012; Spengler & Hronek, 2011). Loss in outdoor recreational settings such as injuries and deaths has the potential to undermine the image of the tourism industry (Bentley & Page, 2008). The attitudes on the part of agency administrators are not only to legal reason but also the moral duty of care that the organization can provide (Barton, 2007; Haddock, 2013; Haddock et al., 1993). Moreover, the failure of ensuring safety can destroy the sustainability of tourism in the wilderness (Eagles et al., 2002). When a tourism activity is not sustainable, the reputation, financial position, staffs as well as the organization objectives are also not stable (Dickson & Gray, 2012).

In sum, providing the health and safety of visitors on wildland recreation sites is the importance of managing an area for a number of reasons. Firstly, there is a moral responsibility for ensuring some protection and minimizing the risks at a reasonable level. Secondly, there is a legal requirement that ignoring to do so may lead to a criminal offense. Lastly, visitor risk management can minimize the risk of litigation that

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an individual may claim against an agency for damages and compensation (Keirle, 2002).

2.2.3 Risk management process

Of course, it is impractical to completely remove risk from outdoor recreation and predicting all potential hazards is also impossible. Moreover, regulating what should or should not be happened to participants is not a good idea (Grant et al., 1996). Eventually, the lacking of absolute control and transferring responsibility conception, outdoor programs inevitably offer risk experiences of incidents (Ewert, 1984). As noted by Clarke (1998) that it is no way to absolutely avoid risk in outdoor pursuits. Therefore, ensuring appropriate standards to provide safety for outdoor recreationists is necessary (Grant et al., 1996).

Risk management strategy is applied to ensure people's safety by decreasing the incidence and understanding the nature and prevalence of the incident which is the fundamental step for allocating resources and informing efforts to decrease the likelihood of incident (Gaudio et al., 2010). Learning from past incidents is typically critical for wildland recreation management to identify the nature of incidents that occurred (Gstaettner, Kobryn, et al., 2019). The understanding of uncertainties related to outdoor activity needs to clearly communicate as part of the risk management process to participants. For this reason, there is a need to gather data, analyze, and learn from what has happened before (Dickson & Gray, 2012).

The process of visitor risk management is continuous (Dickson, 2002). It is included the collective procedures used to deal with the incident before, during, and after proactively in trying to keep risks and losses at an acceptable level (Dickson &

doi:10.6342/NTU202103140

Gray, 2012). Steps presented by a number of risk management models can be ranged from two or three up to eight steps but the simplest and unencumbered one is composed of four steps proposed by Spengler & Hronek (2011) (see figure 2.2).

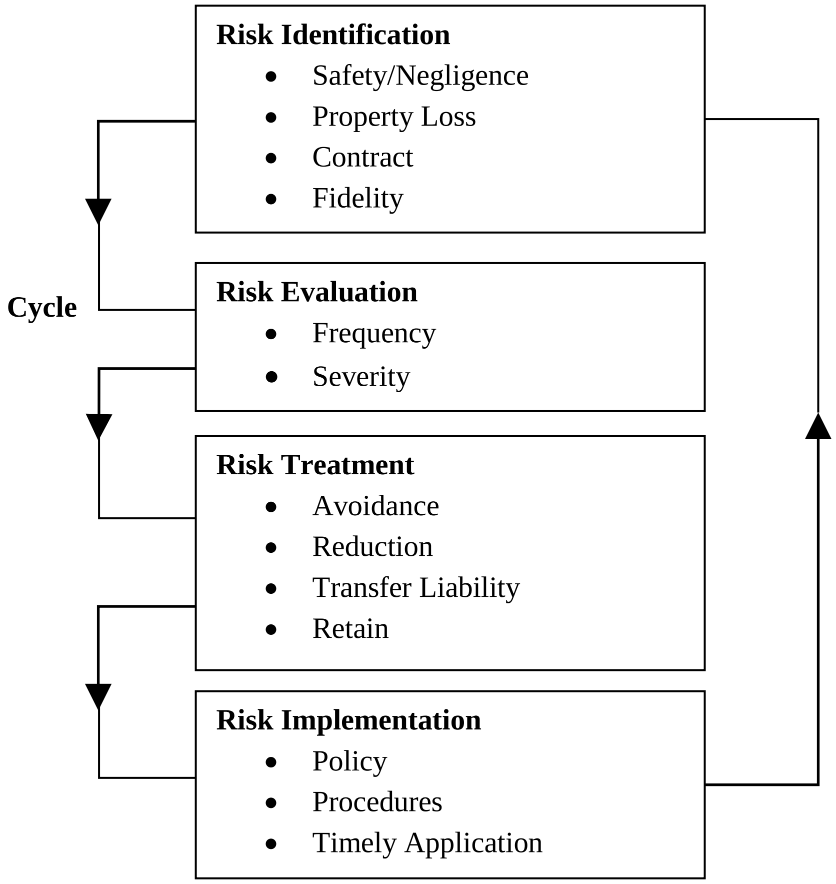

Figure 2.2 Risk Management Model(source: modified from Spengler & Hronek, (2011))

Risk identification is the first process of developing a list of the risk engaged in an activity or setting (Department of Conservation and Land Management, 1998). This process can help an organization answering the questions: what are the possible losses? what could go wrong? and what causes the losses? (Haddock, 2013). More than identifying the risk inherent in the activity, the organization can identify the causal factors associated with activity regarding people, equipment, and environment (Haddock, 2013; Haddock et al., 1993). More specifically, Spengler & Hronek (2011)

doi:10.6342/NTU202103140

indicated the risk identification in recreation, sports, and tourism is related to safety, negligence, property loss, contract, and fidelity issues. Spengler & Hronek (2011) also suggested that knowing where incidents took place and keeping active in learning about past lessons helps an agency or organization identify risk. Sometimes, to get a clear picture of what causes the risks, the organization needs a fresh perspective from new people who are not familiar with the surroundings (Spengler & Hronek, 2011).

Risk evaluation is related to the details about the frequency and severity of incidents (Department of Conservation and Land Management, 1998; Spengler & Hronek, 2011). This step follows with accessing the likelihood of the frequency and probability of incident which helps to evaluate the number of people at risk and the severity of an incident (Department of Conservation and Land Management, 1998). Specifically, frequency is about the potential or the likelihood that an incident will arise while severity is about the type of incident ranging from minor scrapes to paralysis or mortality (Spengler & Hronek, 2011).

Risk treatment is the process of making decision to determine a control measure in dealing with the risks (Department of Conservation and Land Management, 1998; Spengler & Hronek, 2011). There have four basic manners to treat risk including retention, reduction, transfer, and avoidance (Spengler & Hronek, 2011). Retention is a choice of keeping the risk at the original level without any interventions because the risk is deemed to be low or within acceptable limits (Department of Conservation and Land Management, 1998; Haddock et al., 1993; Spengler & Hronek, 2011). Reduction is an action to reduces the risk of an incident (Spengler & Hronek, 2011). This reduction is also included reducing the risk probability and minimizing the severity of the incident (Department of Conservation and Land Management, 1998). In doing so, the risk

doi:10.6342/NTU202103140

reduction approach requires skills and knowledge of appropriate safety applications to mitigate the risk in the activity (Haddock, 2013). Transference is the shifting of the risk to another party through insurance, contracts, or agreements (Spengler & Hronek, 2011). Transfer liability can also be done by providing participants the risk information and allowing them to make their informed decision. Doing in this way, the participants take responsibility themselves. (Department of Conservation and Land Management, 1998; Haddock et al., 1993). Avoidance is a manner of canceling or prohibiting the activity as well as close the facility (Spengler & Hronek, 2011). Avoidance is recommended when the frequency and severity are over an acceptable range despite attempts to manage them in other possible techniques (Haddock et al., 1993).

Risk implementation is the actions of risk treatment that reasonably implemented in a timely and effective way. Risk implementation is carried when something is adjusted, changed, or built by taking the form of policy change, verbal warnings, brochures, signs, etc. (Spengler & Hronek, 2011).

The series of risk management processes must be continually monitored and reassessed especially the effectiveness of control measures. Reviewing the proposed risk treatment helps to make sure that applying the control measures can really reduce risks without introducing new risks to a program (Department of Conservation and Land Management, 1998).

2.3 Human factors and incident risk

In wilderness tourism, tourists are likely to enjoy benefits without awareness about hidden risks (Gstaettner et al., 2017). The characteristics of people visiting are important to management agencies that need to rely heavily on the knowledge of

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incidents, near misses, and hazards in the process of planning (Gstaettner, Lee, et al., 2019). Individual characteristics such as age, gender, medical and psychological condition are possibly the risk factors of incidents (Angert & Schaff, 2010; Heggie, 2006a). Heggie & Küpper (2018) emphasized that some human factors (e.g., age, gender, preexisting health conditions, physical condition, and prior experience) may lead to an incident by one or multiple factors combined. The connection between risk factors in population concern and incidents encountered requires outdoor managers to have a more comprehensive assessment to visitors, for example, as described by Honigman et al. (1993) and Basnyat et al. (1999) that age, preexisting medical condition, previous history of altitude sickness, and place of residence at sea level are independent factors of Acute mountain sickness (AMS) in high-altitude mountaineering. Therefore, age, physical condition, cognitive condition, and emotional condition need to be considered for the outdoor recreation safety since all can impact the welfare of participants (Skaros, 1998).

Various evidence has been explained the relation between human factors and potential incidents. Arendt (1996), for example, explained the relationship between gender and injuries that women may sustain more injuries than men as a result of wider pelvis and Q angle at the knee of the women's lower leg alignment. Moreover, younger males are more frequently engaging in recreational activities which some will have more relaxed attitudes and change their personal behavior when engaging in recreational activities (Ewert & Hollenhorst, 1994; Page & Meyer, 1996). Moreover, the difference of risk awareness between male and female tourists is also highlighted and seriously considered for risk management. For example, young adult males are

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considered as high-risk takers since their risk-taking propensity which they are the most frequent incident encountered group while swimming (Parkin & Morris, 2005).

Visitor's age is another human concern in many outdoor recreations. Even though age, sometimes, is not considered as a restriction for traveling because well planning and prevention are more important for a safe journey but in general, elderly travelers need to take more special precautions during the trip as well as several recommendations before embarking on the trip (Ramos-Sesma et al., 2018). In previous research, for example, the emergency evacuation in Everest region were more common among older trekkers (Leshem et al., 2008). Not only geriatric populations that required more attention in wilderness tourism, children populations are also vulnerable to incidents, as described by Skaros (1998) that both children and older adults have a lower tolerance for dehydration and higher potential for sunburn. Older populations have more potential risk for chronic diseases, heart and respiratory problems, sudden cardiac problems whereas children populations have more potential risk for respiratory compromise or failure and less likely of fracture as well but there will be more serious when the fracture happens in children group (Skaros, 1998).

Apart from the visitor's age, the preexisting medical condition is another concern that seems to be connected together. Many people traveling in remote areas around the world are elder and have preexisting medical conditions (George Washington University & Adventure Travel Trade Association, 2013). Moreover, because of the chronic medical problem, older travelers are likely to take medications that may lower the endurance abilities to environmental and physical stresses (Skaros, 1998). Traveling with preexisting medical conditions has a risk of developing trip-related symptoms (Ramos-Sesma et al., 2018). Ill or injured participants are at greater

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risk of reinjury, dehydration, exhaustion, and less likely to help themselves when an emergency occurs (Skaros, 1998). This dilemma has been disclosed and highlighted by Keyes et al. (2016) in the epidemiologic survey of Himalayan trekkers in Nepal. Keyes et al. (2016) revealed that an extensive range of medical conditions present in travelers could pose difficulties onsite especially the problem of polypharmacy. The understanding of the medical problem of participant can help outdoor agencies to prepare for the adverse effect and appropriate level of management (Barton, 2007; Keyes et al., 2016) as well as providing the right information for visitor's preparation (Keyes et al., 2016; Ramos-Sesma et al., 2018).

Furthermore, the levels of experience and knowledge of visitors are also the independent predictors of the risk of incidents. Experienced visitors have a better ability to estimate real risks more correctly while a visitor who lacking in knowledge or experience may have a misperception or not realize the existing risks in the environment (Grant et al., 1996). The misleading of visitors to the inherent risk from their absence of experience can lead to a lack of preparations and faulty behaviors such as ignoring safety information, not carrying appropriate supplies, alcohol consumption, etc. (Gstaettner et al., 2018; Heggie, 2006b).

2.4 Environmental factors and incident risk

The more people participate in outdoor or wilderness activities in extreme and remote environments, the higher number of accidents, injury, and illness occur in these areas (Goodman et al., 2001). Absolutely, nature is one of the contributing factors of incidents encountered by outdoor recreationists. In general, visitors participate in a natural environment with their own unique picture of reality based on available

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information whether the information is biased or not (Jeuring & Becken, 2013). They are expected to instruct themselves about the inherent risk at the recreational sites, suitably prepare and avoid the onsite environmental risks (Rickard, 2014b). Therefore, risks to travelers originating from natural environments need to be identified for accurate perception of people.

Wind, weather, water temperature, air temperature, humidity, topography, cloud cover all involve traveler tolerances (Skaros, 1998). Several adventure tourism operators noted that instead of removing all risk, some risks have been kept and managed in the outdoor environment to retain a degree of realism while others augured that the natural environment such as topography, weather condition, and environmental changes, was outside the control (Bentley et al., 2004). It is not easy to estimate what condition of nature is the onset of incidents in the outdoor environment but sometimes the incident can happen instantly when certain people or environmental factors are met (Heggie & Küpper, 2018). Two underlying environmental factors covered in this dissertation are topographical and weather factors.

2.4.1 Topography factors and visitor incidents

Topographical features in nature tourism settings create a wide variety of risks from geohazards (Tuler & Golding, 2002). Remarkable landscape and geographic features that attract a large number of visitors to overcome can place people at higher degrees of risk at the same time (Dingwall et al., 1989). The topographical or terrain hazards such as the effect of elevation may not be conscious to people who have limited experience (Rickard, 2012). In high altitudes area, visitors may encounter altitude sickness because of the thinner air resulting in less available oxygen to the body

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(Gilchrest, 1998). Altitude sickness causes symptoms such as fatigue, vomiting, headache, dizziness, and disturbed sleep (Bauer, 2001). Wandering to a high-altitude area is related to many concerns. It is an issue for asthmatics and a visitor who has a problem of respiratory and cardiac-related problem. It increases the effects of solar radiation on people when reflected off snow or water. Moreover, because of the atmosphere's lower oxygen content, bleeding is much harder to control including neurological functioning, behavior, and thought processes are also diminished (Skaros, 1998).

Because the environment is changing over time, also, risks from topographical conditions are often unpredictable. Unstable terrain, slippery ground, and unstable cliffs are some instances of hazardous geographical conditions (Gstaettner et al., 2018). Uncertainty of environments is everywhere in every activity and varies from time to time. In alpine areas, hikers have to walk off established trails into less stable routes in case of retreating glaciers introducing frequencies of rockfall and slope instability (Haegeli & Pröbstl-Haider, 2016). In summer, mountain activities such as hiking, mountaineering, and trekking are more potential risks of slips and falls due to the dynamic nature of the environment (Haegeli & Pröbstl-Haider, 2016). Slips and trips can occur when a person loses traction with the ground owing to wet or slippery surface or when a visitor accidentally strikes or collides with an object on the ground such as tripping over an exposed root resulting a loss in balance and fall on the level (Gstaettner, Kobryn, et al., 2019). The concern of topographical factors is important to visitor behavior. The study of Tuler & Golding (2002) noted that among 38 overall risk conditions, topographical conditions such as gradient were perceived as the medium or high importance factors leading to injury by nature tourists.

doi:10.6342/NTU202103140

2.4.2 Weather conditions and visitor incidents

Weather and climate are important ingredients in tourism and recreation potential (Matzarakis, 2006). Weather and climate impose the attractiveness of a tourist destination but, at the same time, these components inherit some likelihoods of incidents. Weather conditions or weather changes really threaten visitor safety as responded by 97% of New Zealand Adventure Tourism operators and about 29% of operators rated weather conditions as the number one threat to visitor safety (Bentley et al., 2004). Similarly, most of the operators of Queensland adventure and ecotourism identified adverse and changeable weather conditions as risk factors to the client injury (Bentley et al., 2010).

Inclement weather can bring thunderstorms, hail, snowfalls, wind, rain, heat, and cold and more risk to individual safety (Gilchrest, 1998; Silver & Conrad, 2010). Negative consequences of weather conditions can reflect in health and well-being of people from psychoemotional reactions to physiological processes that can cause clinical disorders, illness, and even dying (Katerusha & Matzarakis, 2015). Changes in weather conditions can be sudden and drastic without any warnings (Dickson & Gray, 2012; Skaros, 1998). People who have limited experience with related extreme weather circumstances can suddenly become high risk (Skaros, 1998).

Temperature and humidity are the fundamental parameters that can determine the environmental stress in the human being (García, 2019). Extremes of temperature whether heat or cold are also considered as severe weather conditions (Dickson & Gray, 2012; Skaros, 1998). Decreasing ambient temperature can lead to hypothermia resulting in the dropping of body temperature below 35 °C which may be occurred in many

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activities such as mountaineering, skiing, swimming, underwater diving, etc. On the other hand, rising temperatures may lead to heat-related conditions or hyperthermia (Bauer, 2001). Heat accumulation may expose tourists to dehydration, heat exhaustion, and heatstroke (Auerbach, 2015a; Skaros, 1998). Typically, to regulate the body temperature, the human body will respond by sweating through the skin encouraging evaporation, but in an extreme humidity environment, this cooling mechanism will be hindered (Auerbach, 2015b). The humidity of the air promotes more accumulation of heat in the human body and makes everything worse at all temperatures (Auerbach, 2015b). Apart from temperature-extremes of hot or cold, both rainfall and drought also directly affect people wellbeing (Ahern et al., 2005). Even on an established hiking trail, rain or snow can pose a risk to visitor safety as of its hazardous unpredictable condition (Rickard, 2012). On a wet day, a simple walking down a small rocky creek can significantly put tourists at higher physical risk than on a dry day (Dickson & Gray, 2012). Slippery ground after rainfall or snow (Tuler & Golding, 2002), moss, wet rock, as well as the combination of slippery footing and water can be perilous to visitors (Rickard, 2012).

It is clear that extreme weather conditions introduce the incidents such as hot weather engaging individuals suffering heat exhaustion or dehydration resulted in the discontinuance of travelling owing to severe weather conditions such as sudden weather changes (e.g. hail, storm) (Gstaettner, Kobryn, et al., 2019). Obviously, different weather condition introduces different risks (Dickson & Gray, 2012). Promoting recreationists and tourists to understand weather risk information and forecasting is critical for risk management both in commercial and noncommercial operations (Bentley & Page, 2008). Therefore, the potential impact of weather should be

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contemplated at the first stage of risk management and the dynamic nature of weather should be integrated into as a continuing risk management process within the daily operation (Dickson & Gray, 2012).

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Chapter 3 Methods

3.1 Study area

This study was conducted in Xitou Nature Education Area (XNEA), Taiwan (R.O.C.), which is administered by the Experimental Forest, College of Bio-resource and Agriculture of National Taiwan University. It was founded in 1901 as an experimental forest during the Japanese occupation of Taiwan. However, since 1970 it has been organized as a forest recreation area, promoting academic research, education, resource conservation, and forest management demonstrations (Yu et al., 2019). XNEA is one of the most famous forest recreational sites in Taiwan and serves about 2 million visitors yearly (The Experimental Forest, College of Bio-Resources and Agriculture, 2018). The well-known tourist spots in the XNEA, such as the Forest Ecological Exhibition Center, University Pond, Memorial Pavilion, Giant Tree, Ginkgo Bridge, and Sky Walk, are connected to trails (Figure 3.1). Besides, museum, e-shuttle, restaurant, and accommodation are provided inside. Tourists can enjoy indoor exhibitions and outdoor recreation activities on nature trails which are well-organized within the area and provide different difficulty levels. Especially the natural trial network connecting visitors to three vegetation zones including coniferous, broad-leaved, and bamboo forests which they can enjoy with open air activities such as picnicking, hiking, outdoor sightseeing, forest therapy programs, social interaction. Covering almost 2,350.50 hectares, the elevation of XNEA's trail network varies from 800 m to 2,000 m. XNEA is a subtropical forest located in the mountainous region of central Taiwan and is commonly known for its high humidity and a lot of rain. The temperature there is warmest in August and coolest in January. The annually temperature range is between 11°C and 28 °C. (The Experimental Forest, College of Bio-Resources and Agriculture,

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2018). XNEA is a concave valley enclosed by mountains to the east, west, and south. It is also widely known for rich biological resources, with around 300 tree species, 1,300 herbaceous species, 96 bird species, and 20 species of reptiles (Chiou et al., 2013).

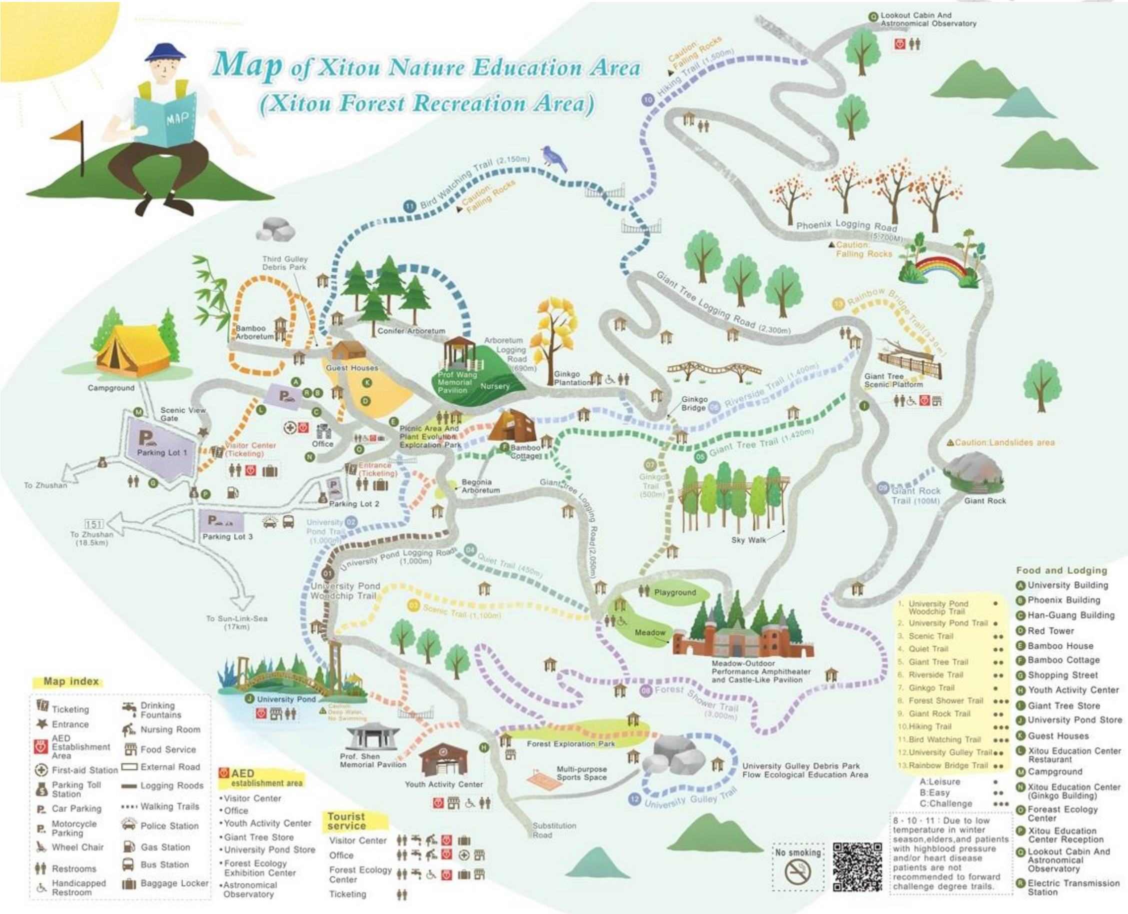

Figure 3.1 Map of XNEA with trail routes (The Experimental Forest, College of Bio-Resources and Agriculture, 2018)

3.2 Data collection

The data applied in this research was approved by the Research Ethics Office of National Taiwan University (NTU-REC No. 201906HM013). Four major data were included and investigated in this research composed of incident data, preexisting health conditions of patients, weather data, and topographic data. The incident data whether illness or injury cases were reviewed from the rescue patient record of XNEA's

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Emergency Medical Service from July 2012 through June 2018. These records were noted by medical service teams, which were each composed of a nurse and rescue specialists. They summarized patient information, preexisting health conditions of patients, location of incident, and other details of the incidents as recounted by patients and/or witnesses. In this research, we define illness as any interruption, cessation, or disorder of functions, system or organs and represents an experience of unhealth of body and mind that required emergency medical care whereas injury is defined as any unfavorable, abnormal, or adverse events which result in damage to physical health or damage to a visitor that required emergency medical care.

The weather data were automatically recorded by XNEA's weather station located in the center of XNEA. The lowest and highest temperatures were measured and then the average temperature (ºC) was achieved for each day (Wan et al., 2020). Daily relative humidity was also obtained and then showed as a percentage. Rainy condition was captured as a dummy variable and has been marked "1" if the precipitation was indicated more than 0 mm. on a certain day (Tsubota et al., 2018).

The topographic data integrate the average elevation (m.) and average slope (%) of each patient incident. For every single day, the location where each patient encountered an injury was retrieved and its elevation and slope were normalized using Digital Elevation Model (DEM) with a 20 m × 20 m resolution in ArcGIS (ESRI, Redlands, California) and then the average elevation and slope were calculated from the elevation and slope value of every victim.

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3.3 Data analyses

3.3.1 Illness, injury, and patient characteristics

We examined all emergency records to inform the descriptive information regarding the frequency and percentage in victims' profiles and incident-encountered characteristics. Then, the illness and injury cases distribution map (hot zones) were depicted using ArcGIS software. Further, to illustrate the real level of incident risk, illness and injury rates that take the level of exposure into account were calculated dividing the number of incident cases by the level of incident exposure (Bailer et al., 1997; Dickson & Gray, 2012). To estimate the incident exposure level, we explored tourist registration records to attain the number of users. We calculated the rate at a unit of per 1,000 person−days by relating the number of people who experienced incident as the numerator to the total number of annual travelers as the denominator to observe the trend throughout the six-year period of the study.

3.3.2 Illness and human factors relation

In response to the second research question aiming to investigate the relationship between visitor's preexisting health conditions and illnesses experienced by forest visitors, we hypothesized that a visitor's chronic disease or disorder is related to the illness encountered. Furthermore, the relationship between sex and experienced illness was analyzed. A chi-square test was employed for significance testing using SPSS statistics 22 (IBM Corporation, NY, USA). A p value less than 0.05 was considered as statistically significant. Formally stated:

H1: Visitor's preexisting medical condition will relate to their illness encountered.

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3.3.3 Injury and environmental factors relation

In response to the third research question aiming to examine the relationships between injuries encountered by visitors, weather covariates, and topographic factors, two frameworks have been adopted.

First, we hypothesized that the daily injury rate would be influenced by the following weather factors: average temperature (ºC), relative humidity (%), and rain condition (rain/no rain). Totally, 2,182 of working days of XNEA were available for model fitting. Nevertheless, prior to fitting all the data into the model, a boxplot was drawn to detect outliers from the daily tourist number variable and to minimize the impact of outliers. We chose to exclude 31 outliers that exceed the inner fence, 3rd quartile + 1.5(interquartile rage), of XNEA's working days, which covered 17 cases of injury. Finally, 2,151 days were included for model fitting. As demonstrated in Figure 3.2, the number of daily injury cases in each day varies from zero to eight cases which mostly XNEA don't have any injury happened or zero cases accounted for 1,516 days from totally 2,151 days. Therefore, the daily injury was a discrete and rare circumstance with many counts of zero and was not normally distributed. This distribution followed the Poisson distribution. Hence, we used Poisson and negative binomial (NB) regression to fit the model because both of them are the most frequently used in fitting data that is heavily right-skewed (Lord et al., 2005) and is helpful for sensitivity analysis (Thabane et al., 2013). Formally stated:

H2: There is a positive relationship between daily injury rate and weather factors including average temperature, relative humidity, and rain condition.

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Second, we hypothesized that the daily injury rate would be affected by the average elevation (m.) and average slope (%) of every patient found day by day. From 2,151 of XNEA's working days, only 624 observations were usable for further model fitting. This is because when there were no injury cases (zero counts) or at least one unknown injury location was taken to average a value calculation, it meant no topographic data was achievable. Poisson and NB regression were consistent with the data frequency distribution as depicted in Figure 3.3 and were executed to fit the model. Formally stated:

> ***H3:*** There is a positive relationship between daily injury rate and topographic factors including average elevation, and average slope.

To neutralize the varying degrees of daily incident exposures for both assumptions, the number of visitors in each day was considered as the offset variable and integrated in each model. The whole process of fitting the models was analyzed using R Software, version 3.3.6 (R Core Team, 2020) on RStudio, version 1.2.5042 (RStudio Team, 2020). Pearson Chi−Square (X^2), Akaike's information criterion (AIC), Bayesian information criterion (BIC), and log−likelihood function were also calculated to controlled model fits and performance.

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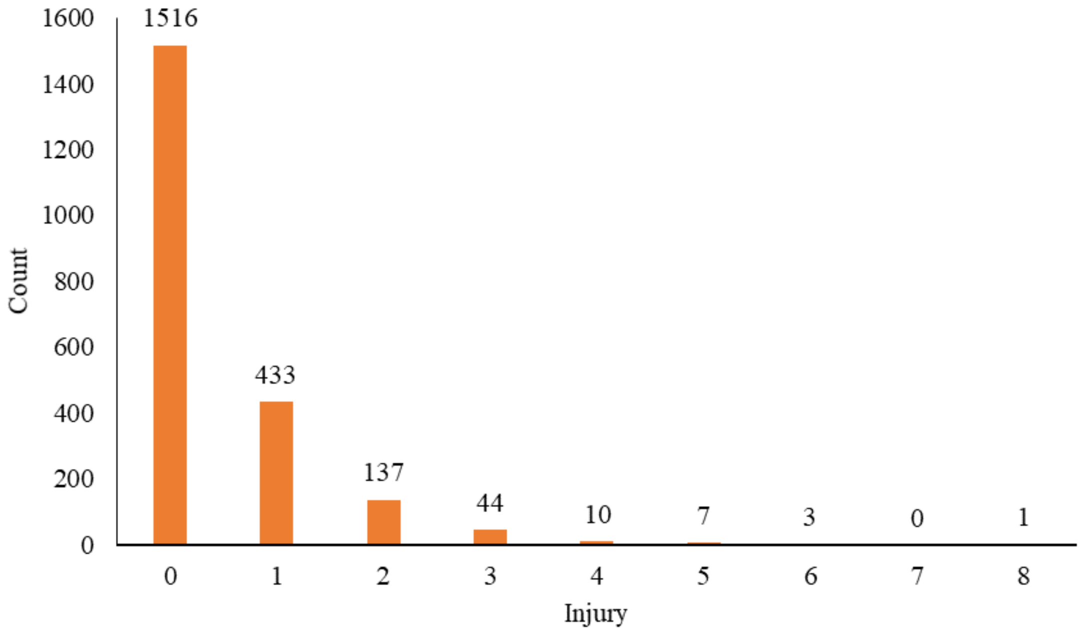

Figure 3.2 The number of daily injuries from July 2012 to June 2018

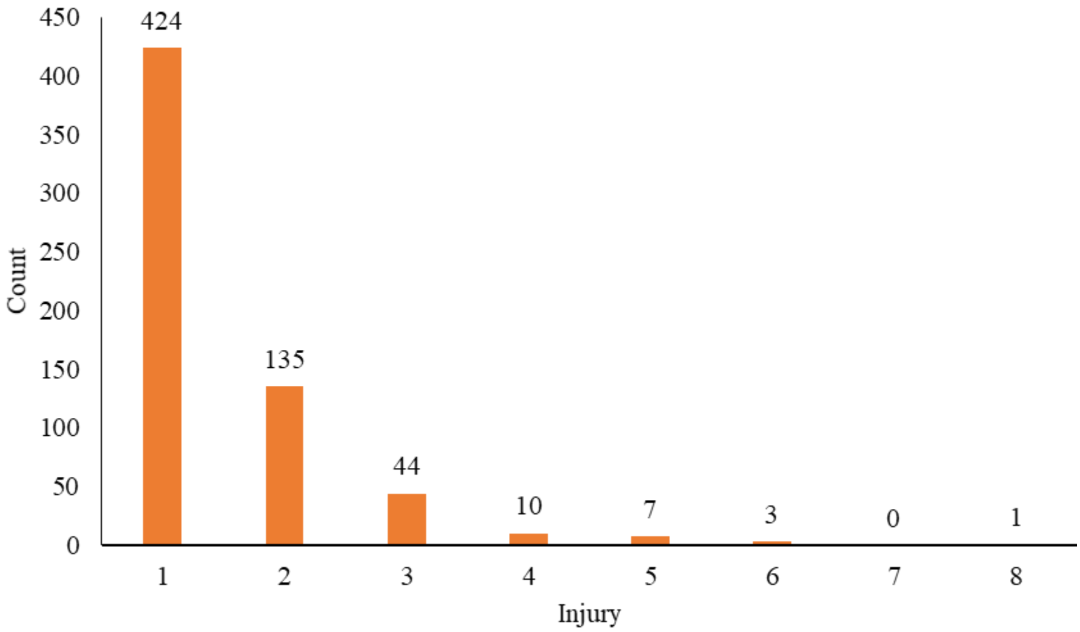

Figure 3.3. The number of daily injuries from July 2012 to June 2018, when geographic information was accessible

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3.3.4 Conceptual framework

The present section covers the study conceptual framework based on the literature review in prior chapter. This section comprises the framework including independent and dependent covariates and their relationships (figure 3.4).

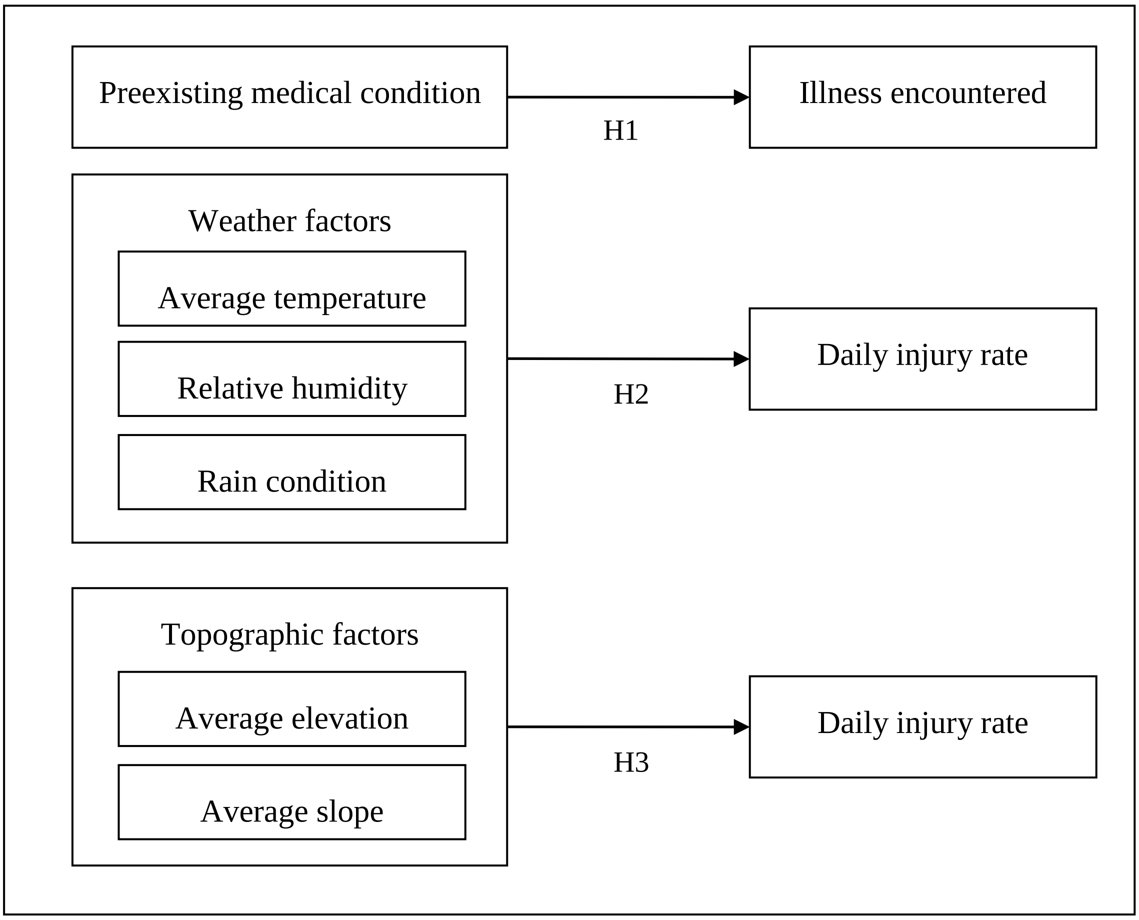

Figure 3.4 Conceptual framework

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Chapter 4 Results and discussion

4.1 Epidemiology of illnesses

Between July 2012 and June 2018, 276 people became ill at XNEA, and the number of illness cases recorded decreased in each of the first 5 years from 83 to 47, 39, 35, and 21 people, respectively, and suddenly increased to 51 people in the sixth year. This is similar to the yearly illness rate, which continuously reduced in successive years from 0.049 to 0.028, 0.020, 0.018, and 0.011 per 1,000 person-days and suddenly increased to 0.023 per 1,000 person-days in the sixth year. Roughly, the average rate of ill people was about 0.024 per 1,000 person–days, or around 3 people experienced illness per 100,000 visitors over the six-year period. The percentage of rescued female people was 56.2%, and that of male victims was 43.5%. The age range was 2–93 years old with an average of 52.3 years, but some people did not inform their age. Age was categorized into five groups, namely unknown, ≤17, 18–39, 40–59, and ≥60 years, comprising 8%, 17.8%, 6.2%, 22.5%, and 45.7% of all victims, respectively. Regarding incident time and season, the data did not show a clear difference in the number of people rescued. The number of patients was little greater in summer (27.5%) than in autumn (25.4%), winter (23.9%), and spring (23.2%), and slightly more patients were rescued in the morning hours (123 people) than in the afternoon hours (113 people). Remarkably, most patients (55.4%) had at least one chronic disease or disorder. Most rescued patients had one chronic disease (44.9%), followed by no chronic diseases (44.6%) and two (6.2%), three (3.3%), and four chronic diseases (1.1%) (Table 4.1; Figure 4.1).

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Table 4.1 Victims' profiles of illness encountered between July 2012 to June 2018

Victims profile	Number	(%)
Years		
July 1, 2012-June 30,2013	83	30.1
July 1, 2013-June 30,2014	47	17.0
July 1, 2014-June 30,2015	39	14.1
July 1, 2015-June 30,2016	35	12.7
July 1, 2016-June 30,2017	21	7.6
July 1, 2017-June 30,2018	51	18.5
Season		
Winter (December – February)	66	23.9
Spring (March – May)	64	23.2
Summer (June – August)	76	27.5
Autumn (September – November)	70	25.4
Incident time		
Morning	123	44.6
Afternoon	113	40.9
Unknown	40	14.5
Gender		
Male	120	43.5
Female	155	56.2
Unknown	1	0.4
Age (years)		
≤ 17 years	49	17.8
18-39 years	17	6.2
40-59 years	62	22.5
≥60 years	126	45.7
Unknown	22	8.0
Number of chronic diseases		
0	123	44.6
1	124	44.9
2	17	6.2
3	9	3.3
4	3	1.1
Total victims	276	100.0

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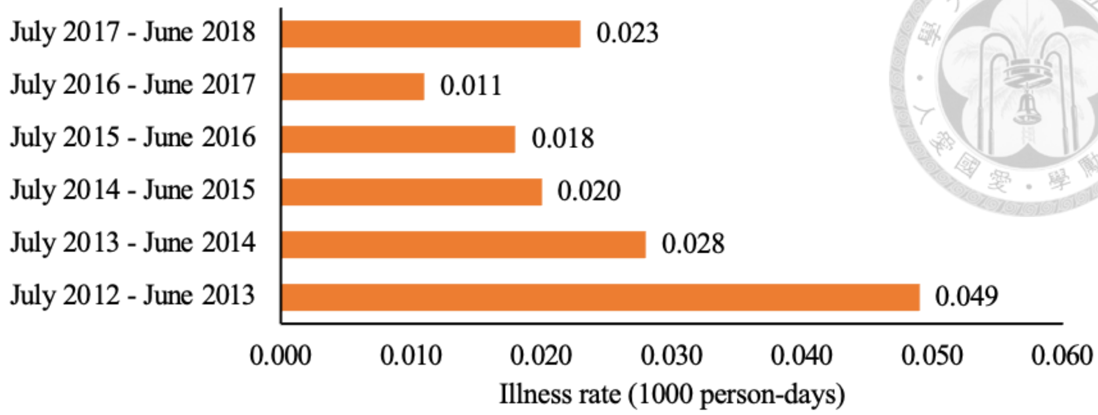

Figure 4.1 Illness rates from July 2012 to June 2018

The quantity and distribution of ill patients grouped into the same location in the study area were encountered over the area. Figure 4.2 interprets illness hot zones in (A) July 2012-June 2013, (B) July 2013-June 2014, (C) July 2014-June 2015, (D) July 2015-June 2016, (E) July 2016-June 2017, and (F) July 2017-June 2018 showing decreased illness cases in most of XNEA locations across six years of study. Figure 4.3 interprets overall illness hot zones in XNEA. Most of the illness cases of XNEA were limited to some of the famous tourist spots, such as the University Pond, Giant Scenic Platform and XNEA's entrances.

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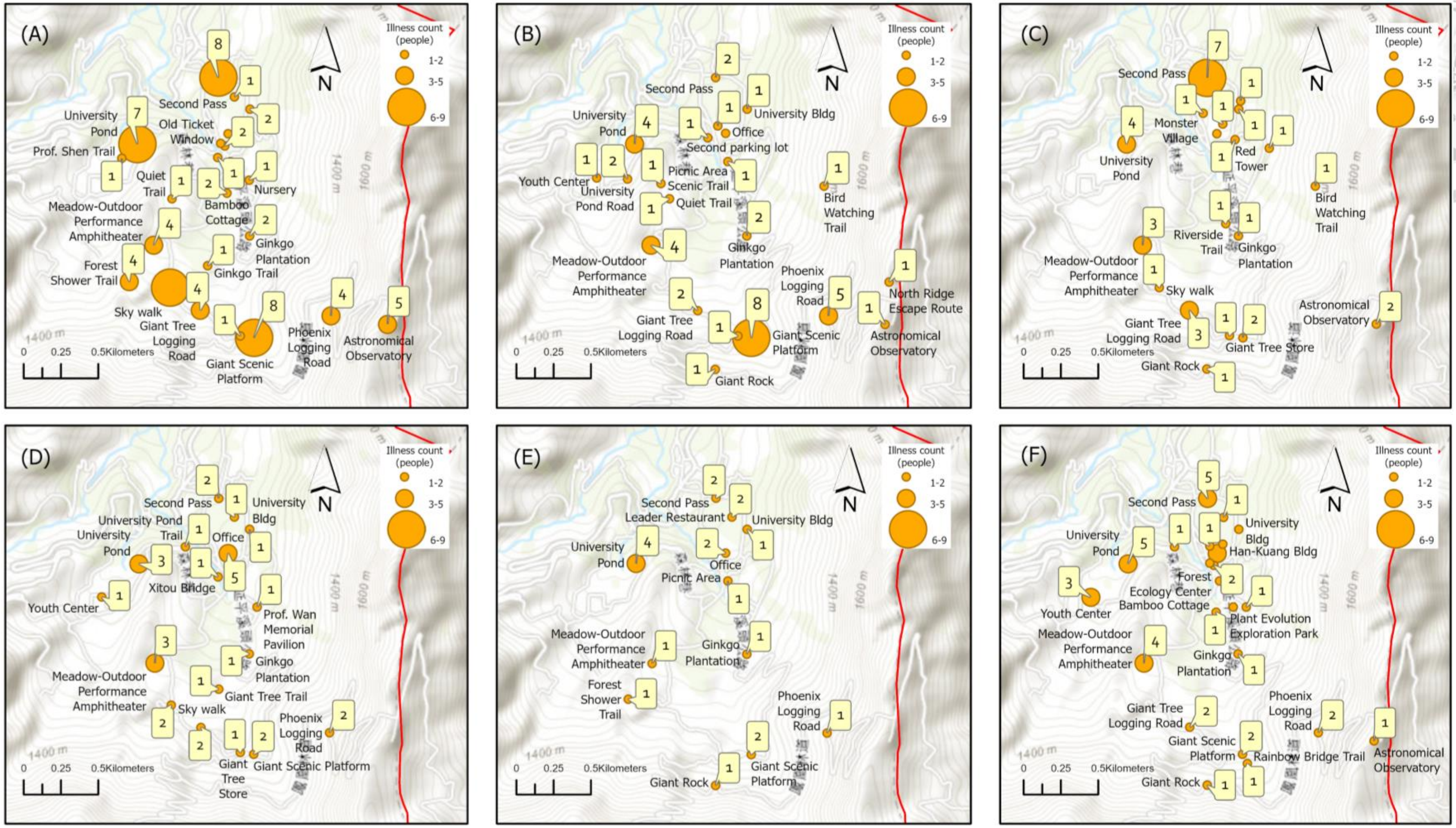

Figure 4.2 Distribution of visitor illnesses in XNEA. (A) July 2012-June 2013, (B) July 2013-June 2014, (C) July 2014-June 2015, (D) July 2015-June 2016, (E) July 2016-June 2017, (F) July 2017-June 2018

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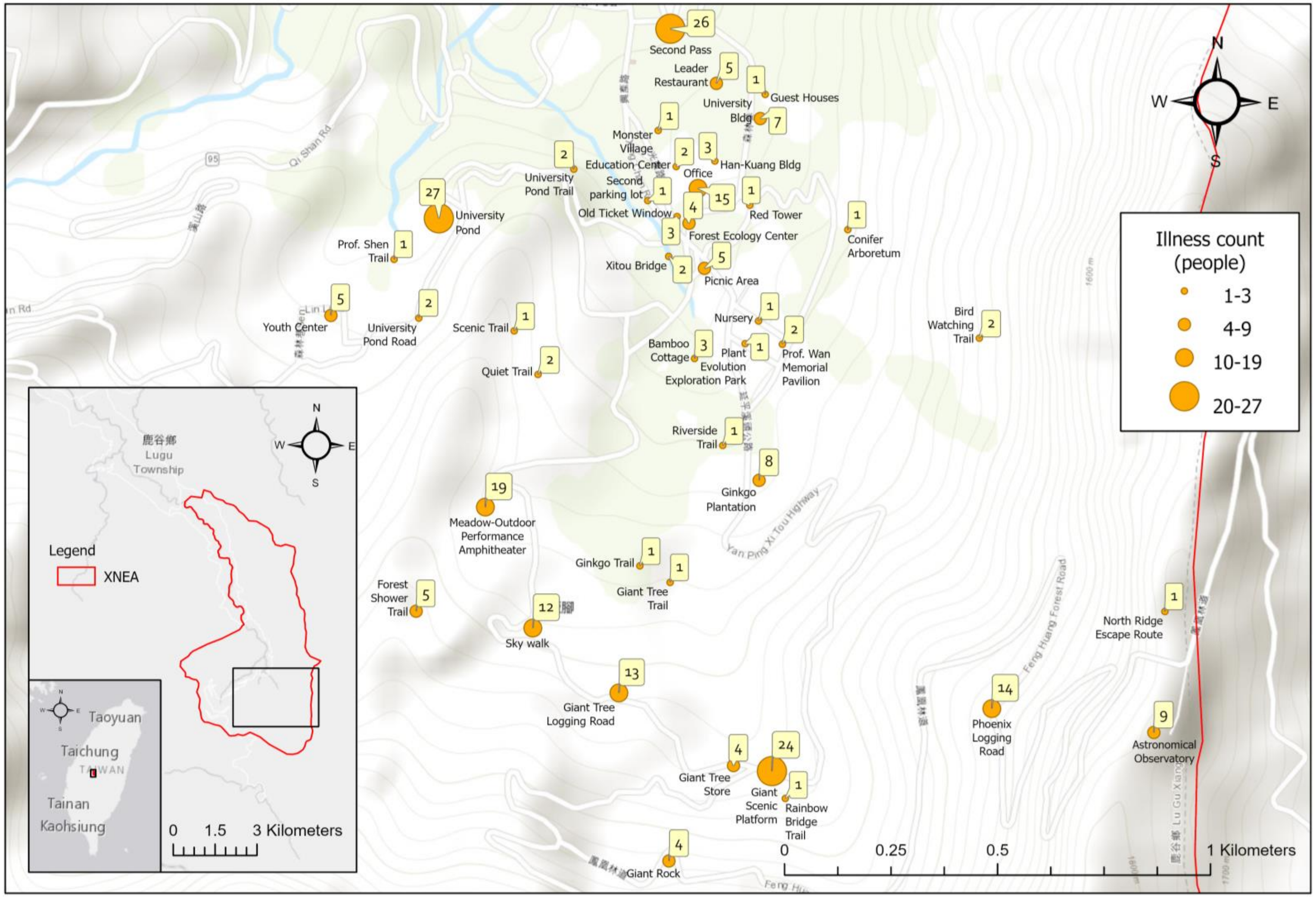

Figure 4.3 Distribution of visitor illnesses in XNEA from July 2012-June 2018

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We broadly classified illnesses into 14 groups based on symptoms. It is worth noting that multiple symptoms could be recorded for one person. Also, all illnesses for everyone were documented and, therefore, the total number of illnesses is higher than the number of ill patients. The most common symptom among the 276 patients studied was dizziness, accounting for 47.8% (Table 4.2). When reviewing age distribution across the five age groups (unknown, ≤17, 18–39, 40–59, and ≥60 years), the elderly population (≥60 years) encountered illnesses more frequently (Figure 4.4). Among the 153 patients diagnosed with preexisting conditions, hypertension was the most common in medical histories (Table 4.3).

Table 4.2 Frequency of illnesses encountered by tourists from July 2012 to June 2018

Illnesses	Number	(%)
Dizziness	132	47.8
Respiratory problems	54	19.6
Nausea or vomiting	53	19.2
Chest pain or chest tightness	46	16.7
Weakness	44	15.9
Syncope	32	11.6
Abdominal pain	29	10.5
Headache	26	9.4
Hyperhidrosis	13	4.7
Seizure	7	2.5
Diarrhea	6	2.2
Fever	5	1.8
Nose bleed	3	1.1
Rash	2	0.7

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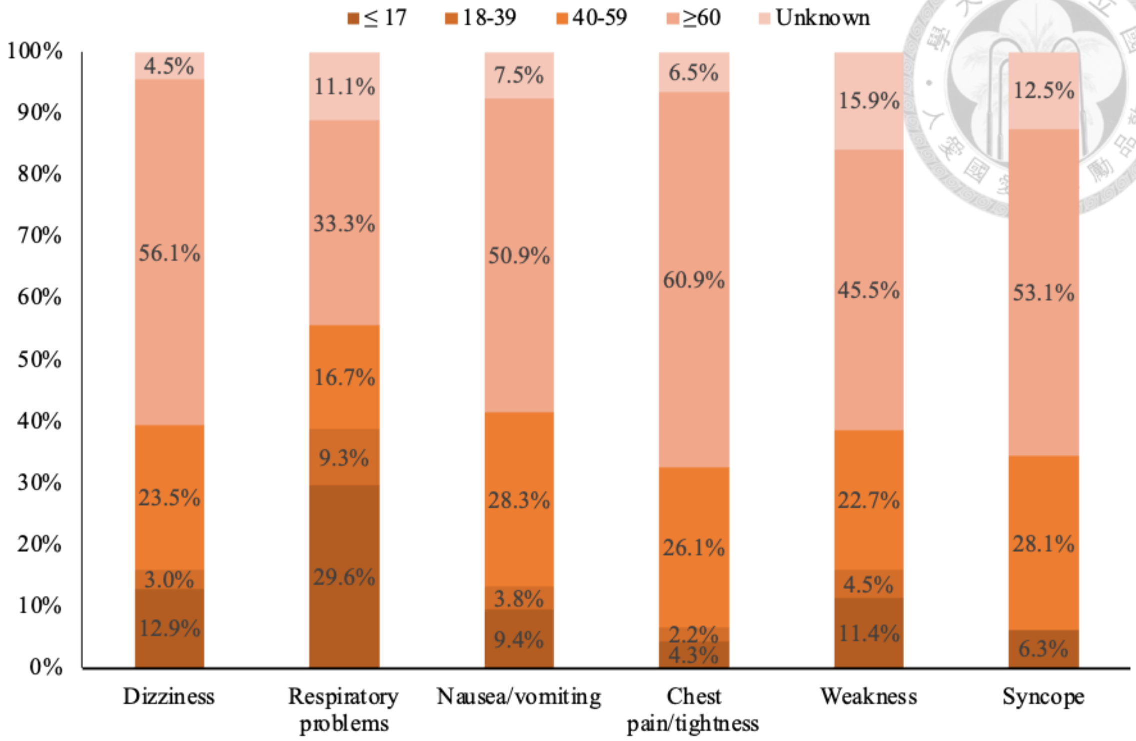

Figure 4.4 Percentage distribution of illnesses by age group

Table 4.3 Chronic diseases and disorders

Chronic diseases and disorder	Number	(%)
Hypertension	72	26.1
Diabetes mellitus or hypoglycemia	35	12.7
Other non-orthopedic problems	26	9.4
Cardiac related	26	9.4
Asthmatic and other respiratory related problems	15	5.4
Cancer	10	3.6
Neurological disorders and stroke	9	3.3
Orthopedic or musculoskeletal problems	2	0.7
Hypotension	3	1.1

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4.2 Visitor's preexisting medical condition and illness relation

The chi-square test demonstrated a significant relationship between sex and illness only for syncope, for which more male patients than female patients experienced the illness. Nevertheless, female patients outnumbered male participants in most cases, the difference between the two groups was nonsignificant (Figure 4.5). Moreover, we designated five experienced illness and chronic disease pairs: (1) dizziness and hypertension, (2) respiratory problems and hypertension, (3) chest pain or chest tightness and cardiac-related problems, (4) weakness and diabetes mellitus, and (5) syncope and hypertension (Table 4.4). Therefore, H1 was supported in that visitor's preexisting medical condition did relate to their illness encountered.

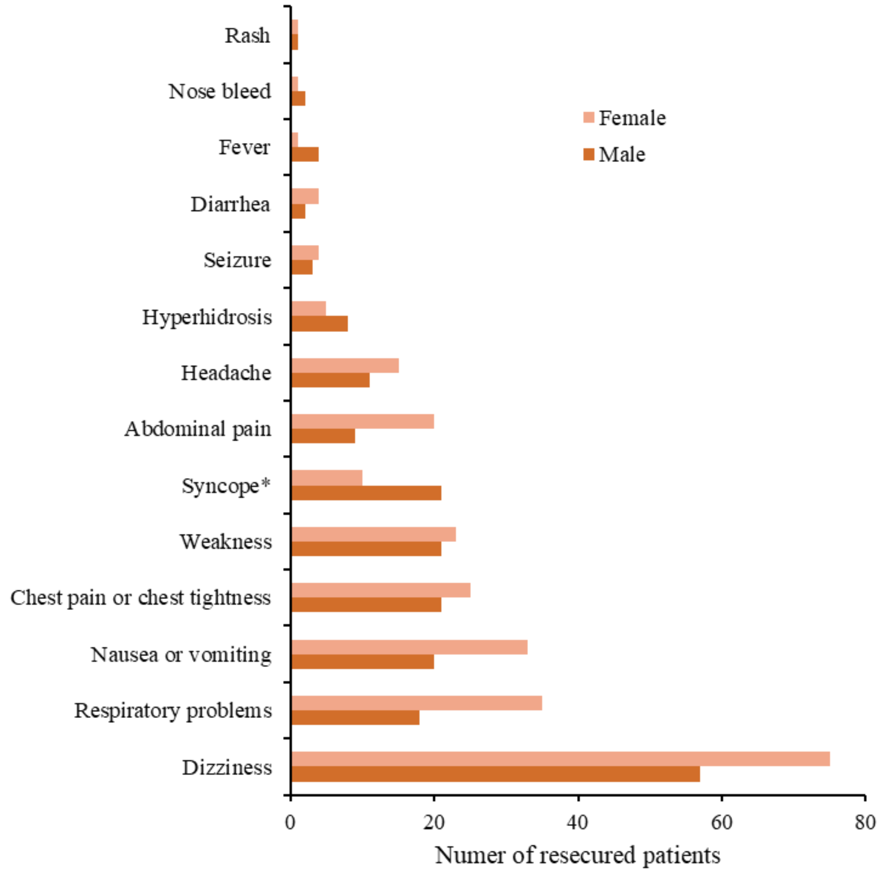

Figure 4.5 Distribution of illnesses encountered by male and female patients rescued

Note: *χ^2 test, p value = 0.004, n = 275, missing value = 1, df = 1

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Table 4.4 Chi-square analysis of visitor chronic diseases according to illnesses encountered (*df* = 1, *n* = 276)

	Dizziness		Respiratory problems		Chest pain/Chest tightness		Weakness		Syncope	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Hypertension	$\chi2 = 11.890$ $p = 0.001$*		$\chi2 = 4.424$ $p = 0.035$*		$\chi2 = 0.000$ $p = 1.000$		$\chi2 = 2.867$ $p = 0.090$		$\chi2 = 8.112$ $p = 0.004$*	
No	119	85	158	46	170	34	176	28	187	17
Yes	25	47	64	8	60	12	56	16	57	15
Diabetes mellitus	$\chi2 = 0.670$ $p = 0.413$		$\chi2 = 0.710$ $p = 0.399$		$\chi2 = 1.106$ $p = 0.293$		$\chi2 = 7.174$ $p = 0.007$*		$\chi2 = 1.204$ $p = 0.273$	
No	128	113	192	49	203	38	208	33	215	26
Yes	16	19	30	5	27	8	24	11	29	6
Cardiac related	$\chi2 = 0.350$ $p = 0.554$		$\chi2 = 0.225$ $p = 0.635$		$\chi2 = 13.588$ $p < 0.001$*		Expected frequency < 5		Expected frequency < 5	
No	129	121	202	48	215	35				
Yes	15	11	20	6	15	11				

Note: * statistically significant

4.3 Epidemiology of injuries

Throughout the six-year period of the study between July 2012 and June 2018, there were 957 injury cases documented in XNEA. The number of rescued patients varied between 98 and 312 persons per year, with a mean of nearly 160 persons per year. The decreasing trend of injured patients from the first year of the study was same as the yearly injury rate. The average rate of injured people was approximately 0.090 per 1,000 person−days, or 9 injured people per 100,000 visitors over the six-year period of the study. Summer months and afternoon hours were the most prevalent periods of

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injury cases. Over the half of injury people (59.6%) were female. The mean age of injured people was about 49 years (range 1−92 y). Most people (71.5%) encountered an injury because of a slip, a trip, or a fall from a height (Table 4.5; Figure 4.6).

Table 4.5 Victims' profiles of injury encountered between July 2012 to June 2018

Victims profile	*Number*	*(%)*
Years		
July 1, 2012-June 30,2013	312	32.6
July 1, 2013-June 30,2014	220	23.0
July 1, 2014-June 30,2015	98	10.2
July 1, 2015-June 30,2016	113	11.8
July 1, 2016-June 30,2017	100	10.4
July 1, 2017-June 30,2018	114	11.9
Season		
Winter (December – February)	160	16.7
Spring (March – May)	190	19.9
Summer (June – August)	344	35.9
Autumn (September – November)	263	27.5
Incident time		
Morning	295	30.8
Afternoon	382	39.9
Unknown	280	29.3
Gender		
Male	382	39.9
Female	570	59.6
Unknown	5	0.5
Age (years)		
≤ 17 years	158	16.5
18-39 years	89	9.3
40-59 years	273	28.5
≥60 years	373	39.0
Unknown	64	6.7

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Table 4.5 Victims' profiles of injury encountered between July 2012 to June 2018 (continued)

Victims profile	*Number*	*(%)*
Injury type		
Slips, trips, or falls	684	71.5
Suddenly happen with unknown reason	88	9.2
Animal related	78	8.2
Equipment	36	3.8
Infrastructure	34	3.6
Accidental hit	15	1.6
Vehicle	11	1.1
Injuries obtained from debris or dust	4	0.4
Falling tree limbs	3	0.3
Unknown	4	0.4
Total victims	957	100.0

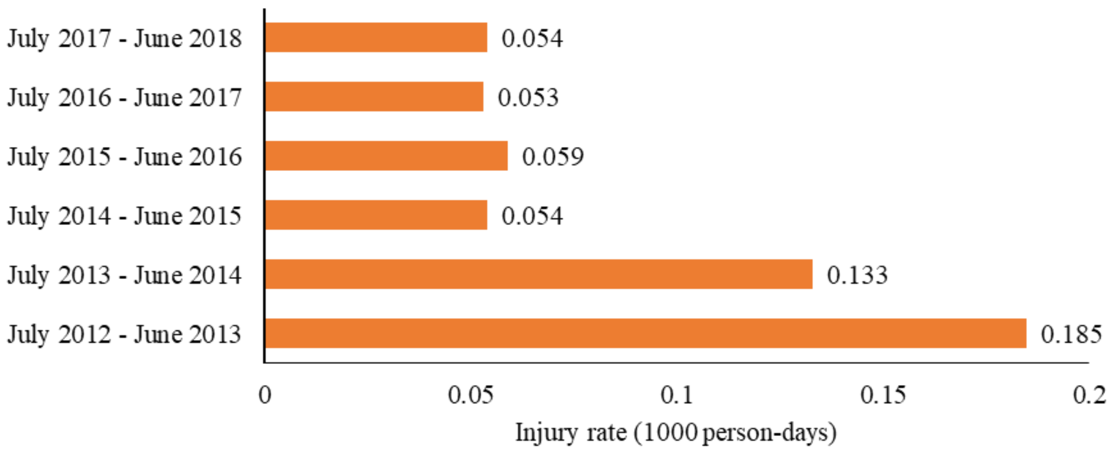

Figure 4.6 Injury rates between July 2012 to June 2018

The quantity and distribution of injured people grouped into the same spot in XNEA were scattered throughout the area. Figure 4.7 shows injury hot zones in (A) July 2012-June 2013, (B) July 2013-June 2014, (C) July 2014-June 2015, (D) July 2015-June 2016, (E) July 2016-June 2017, and (F) July 2017-June 2018 showing decreased illness cases in most of XNEA locations across six years of study. In overall,

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the majority of the injury cases in XNEA were found to some of the famous tourist location, such as the visitor center, University Pond, and XNEA's entrances (figure 4.8). These spots are located at lower altitudes compared to other tourist spots and low slope or flat areas. As shown in Figure 4.9 and Figure 4.10, many injury cases happened between 1,101 and 1,200 meters in elevation and the injury cases were mostly on slopes ranging from 0 to 10%.

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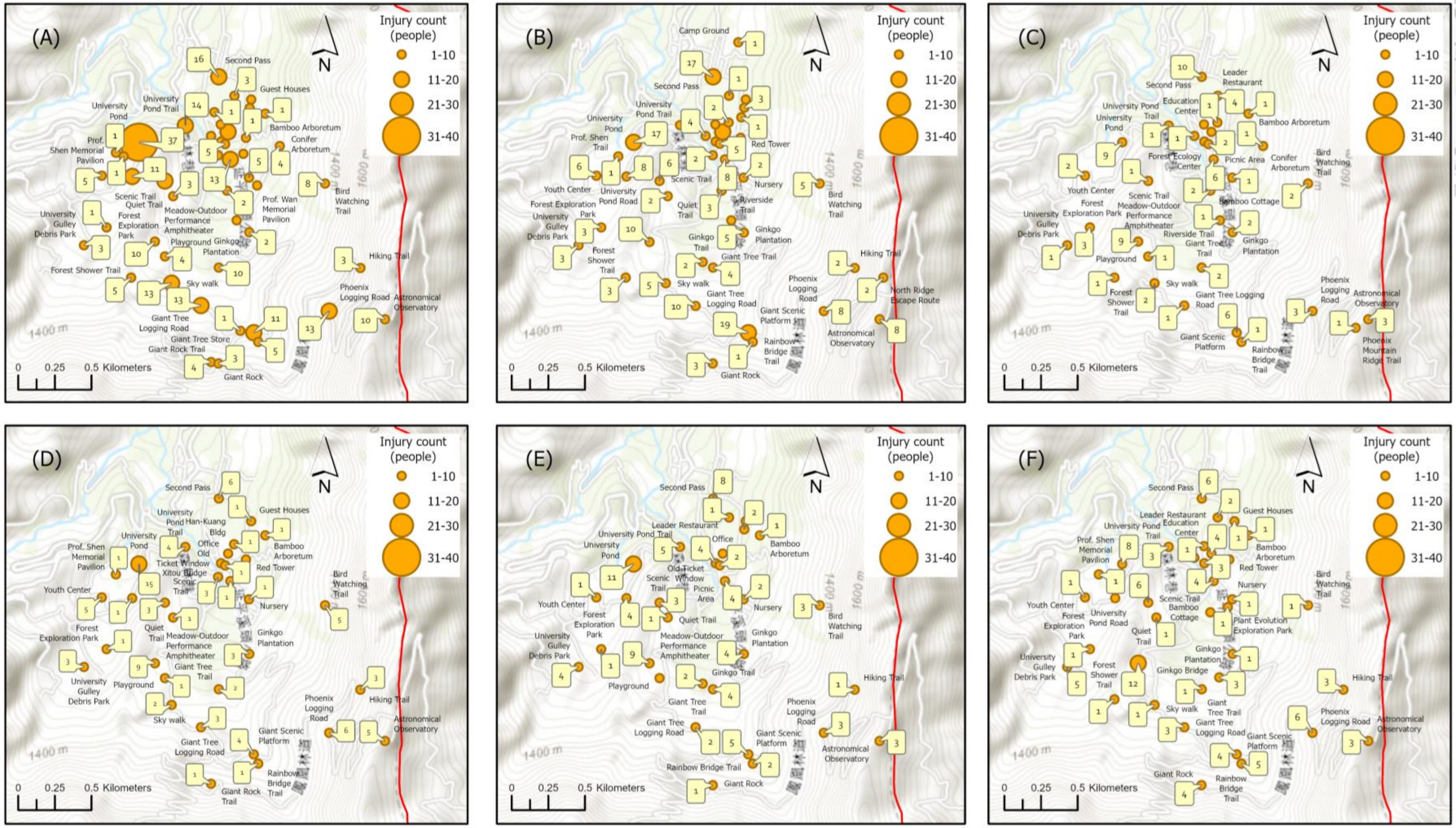

Figure 4.7 Distribution of visitor injuries in XNEA. (A) July 2012-June 2013, (B) July 2013-June 2014, (C) July 2014-June 2015, (D) July 2015-June 2016, (E) July 2016-June 2017, and (F) July 2017-June 2018

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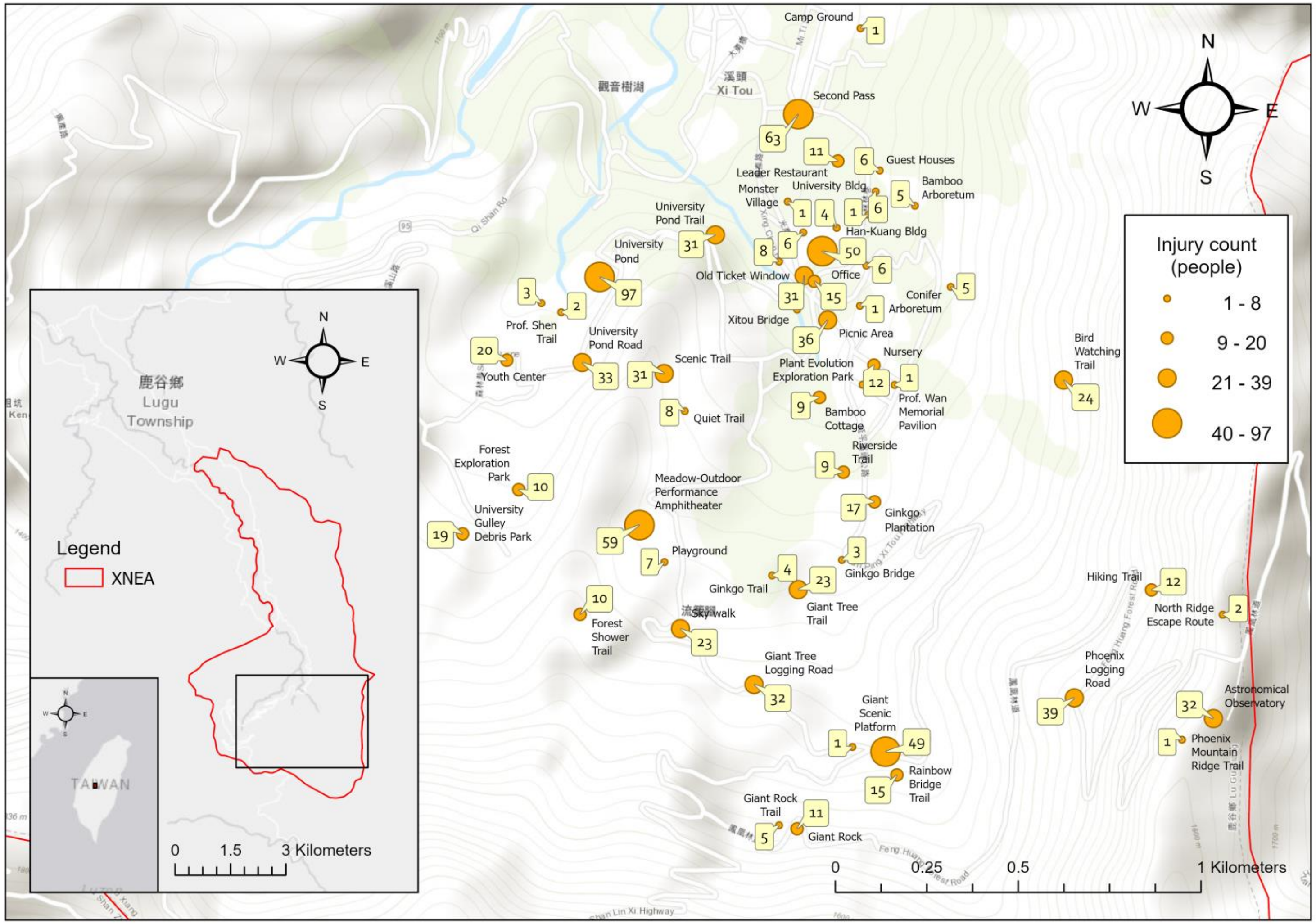

Figure 4.8 Distribution of visitor injuries in XNEA between July 2012 to June 2018

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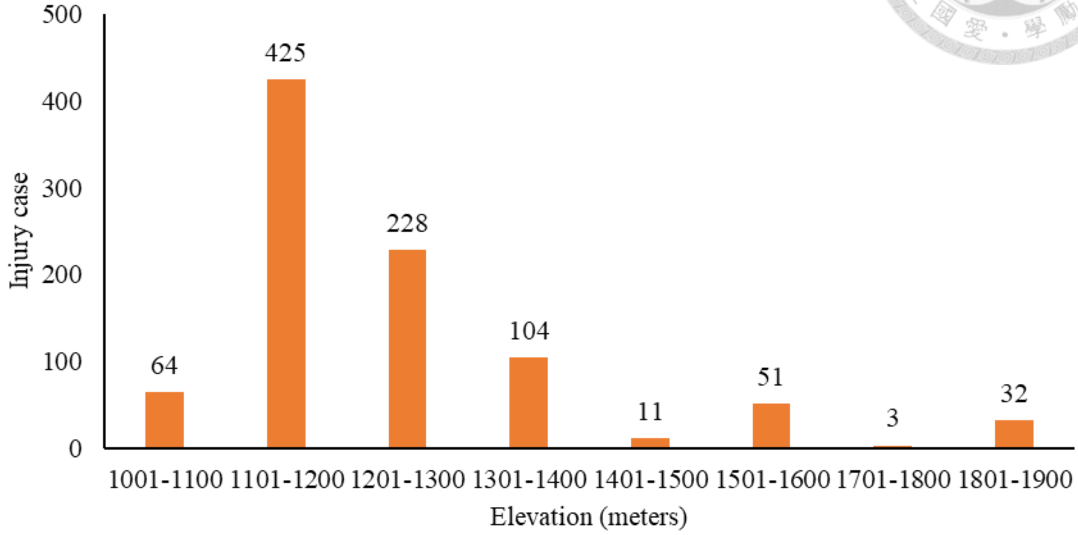

Figure 4.9 Distribution of visitor injuries in XNEA by elevation

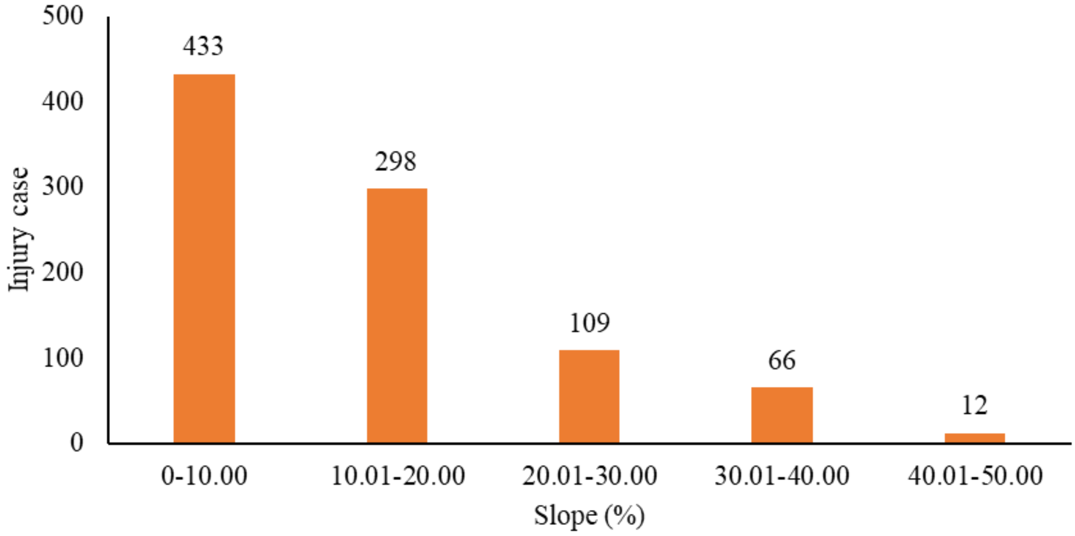

Figure 4.10 Distribution of visitor injuries in XNEA by slope

Table 4.6 illustrates injury-encountered characteristics by injury type and anatomic location of the injuries. It is worth noting that multiple injury types and injured body parts could be recorded for one person. Therefore, all injuries for everyone

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were documented and, therefore, the total number of injuries is higher than the number of injured people. Injuries encountered by XNEA's visitors mostly often involved (38.5%) bruises and abrasions. Ankles, feet, knees, lower legs, and thighs were the most prevalent anatomic region of injury (46.5%), and hands, wrists, elbows, lower arms, and upper arm were the second-most prevalent anatomic region of injury (28.2%).

Table 4.6 Injury-encountered characteristic between July 2012 to June 2018

Injury encountered characteristic	*Number*	*%*
Injury type		
Bruise and abrasion	484	38.5
Pain/swelling	403	32.1
Laceration	157	12.5
Strain and sprain	138	11.0
Fracture/broken bone	39	3.1
Dislocation	13	1.0
Blister	7	0.6
Thermal burn	6	0.5
Unknown	10	0.8
Anatomic location of injury		
Ankle/foot	266	21.2
Knee	241	19.2
Hand	205	16.3
Head	111	8.8
Face	85	6.8
Wrist	71	5.6
Lower leg	68	5.4
Elbow	49	3.9
Back	40	3.2
Lower arm	27	2.1
Shoulder	25	2.0
Pelvis/hip	23	1.8
Thigh	9	0.7
Chest	7	0.6

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Table 4.6 Injury-encountered characteristic between July 2012 to June 2018 (continued)

Injury encountered characteristic	*Number*	*%*
Eye	6	0.5
Neck	6	0.5
Upper arm	2	0.2
Unknown	16	1.3
Total	1257	100.0

4.4 Injury risk estimation model considering weather covariates

Table 4.7 illustrates the descriptive statistics of the weather factors entered into the model to examine the hypothesis that average temperature, relative humidity, and rain condition affect the rate of injured visitors.

Table 4.7 Data used for injury-risk estimation model involving weather covariates

Variable	*N*	*Mean*	*St. Dev.*	*Min*	*Max*
Average temperature (ºC)	2151	17.65	3.86	1.30	29.30
Relative humidity (%)	2151	80.14	14.02	27.7	99.5
Rain condition					
No rain	1551				
Rain	600				
Log of tourist No.	2151	8.45	0.50	1.79	9.28
Injured people count	2151	0.44	0.83	0.00	8.00

The findings of injury risk regressions for the influence of the weather factors average temperature, relative humidity, and rain condition fitting in the Poisson and NB regression model were compared and are descripted in Table 4.8. Based on these findings, H2 was supported in that there is a positive relationship between daily injury rate and weather factors including average temperature, relative humidity, and rain condition. We found the coefficients of all variables in both models to be similar with

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small differences in significance of coefficients. This result supports the consistency and the robustness of the finding under the difference of distributional assumptions. However, the NB regression model provided the grater log likelihood function, smaller AIC, and smaller BIC, attesting the NB model yielded a considerably better fit for the data than did the Poisson regression model. In addition, the Pearson dispersion statistic (X^2/ *df)* for the Poisson model was 1.499, indicating an overdispersion problem, as compared with 1.019 for the NB regression model, providing more evidence of the goodness−of−fit improvement with the NB regression model. As suggested by Payne et al. (2018), the threshold of the Pearson dispersion statistic should not be over 1.2 for the Poisson model, whereas for the NB model it can go up to 1.5.

Table 4.8 The risk estimation models for the effect of weather variables on daily injury rates

	Negative binomial model	*Poisson model*
Intercept	-11.433***	-11.490***
Standard error	0.356	0.308
IRR (95%-CI)	1.083e-05	1.023e-05
	(5.336e-06−2.160e-05)	(5.593e-06−1.870e-05)
Average Temperature	0.019*	0.020**
Standard error	0.011	0.010
IRR (95%-CI)	1.019 (0.996−1.043)	1.021 (1.002−1.040)
Relative humidity	0.020***	0.020***
Standard error	0.003	0.003
IRR (95%-CI)	1.020 (1.013−1.026)	1.020 (1.014−1.025)

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Table 4.8 The risk estimation models for the effect of weather variables on daily injury rates (continued)

	Negative binomial model	*Poisson model*
Rain	0.363***	0.390***
Standard error	0.089	0.070
IRR (95%-CI)	1.438 (1.206−1.714)	1.477 (1.287−1.694)
Pearson Chi-Square (X^2)	2187.875	3217.489
Degrees of freedom (*df*)	2147	2147
X^2/ *df*	1.019	1.499
AIC (Akaike Inf. Crit.)	3725.997	3866.556
BIC (Bayesian Inf. Crit.)	3754.365	3889.251
Log likelihood	-1857.998	-1929.278

Note: *p < 0.1; **p < 0.05; ***p < 0.001

Abbreviations: IRR, incidence rate ratio; 95%-CI, 95% confidence interval

4.4.1 Average temperature

The average temperature passed the significance test at 0.05 in the Poisson regression model and 0.1 in the NB model with a positive association established for the rate of injured people. The exponentiated coefficients of them were also presented IRR at 1.021 for the Poisson regression model and 1.019 for the NB regression model. Specifically, by holding all other covariates constant, when the average temperature increases by 1 ºC, the significance impact of the average temperature contributed a 2.1% and 1.9% increase in the risk of injured people rate in Poisson and NB regression models, respectively.

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4.4.2 Relative humidity

The correlation coefficients of relative humidity were positively significant at 1% level in both Poisson and NB regression models. Both models yielded the same level of IRR at 1.020 contributing to a 2% increase in risk of injury rate without adjusting other variables when there is a 1% increase of relative humidity.

4.4.3 Rain condition

The regression coefficients of rain condition were positive and statistically significant at 1% level in both Poisson and NB regression models. The occurrence of IRR at 1.477 in the Poisson regression model and 1.438 in the NB regression model represent the very solid impact of rainy weather on injury risk. So, when other variables are controlled, rain on a given day increases the risk of injured people rate by 47.70% in the Poisson regression model and 43.80% in the NB regression model.

4.5 Injury risk estimation model considering topographic covariates

Table 4.9 illustrates the descriptive statistic of the topographic variables used in the model that examined the effect of average elevation and average slope on the rate of injured people. The results of the Poisson and NB model investigating these topographic factors are described in Table 4.10. Based on these findings, H3 was not supported in that there is a positive relationship between daily injury rate and topographic factors including average elevation, and average slope. The coefficients of both models are the same. The Poisson regression model provided a lower AIC, lower BIC, than the NB regression model and similar log likelihood estimate with the NB regression model, indicating a slightly better fit in the Poisson regression model. However, the ratio of

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Pearson chi−square to its degrees of freedom being less than 1 in both models signals the occurrence of an underdispersion problem in the dataset.

Table 4.9 Data used for injury risk estimation model considering topographic covariates

Variable	*N*	*Mean*	*St. Dev.*	*Min*	*Max*
Average elevation (100 m.)	624	12.43	1.54	10.87	18.03
Average slope (10%)	624	1.32	0.97	0.00	4.34
Log of tourist No.	624	8.51	0.37	6.90	9.28
Injured people count	624	1.49	0.89	1	8

Table 4.10 The risk estimation models for the effect of topographic variables on daily injury rates

	Negative binomial model	*Poisson model*
Intercept	-7.920***	-7.920***
Standard error	0.293	0.293
IRR (95%-CI)	3.634e-04	3.634e-04
	(2.070e-04−6.542e-04)	(2.070e-04−6.542e-04)
Average elevation	-0.022	-0.022
Standard error	0.025	0.025
IRR (95%-CI)	0.979 (0.930−1.027)	0.979 (0.930−1.027)
Average slope	0.003	0.003
Standard error	0.040	0.040
IRR (95%-CI)	1.003 (0.927−1.084)	1.003 (0.927−1.084)

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Table 4.10 The risk estimation models for the effect of topographic variables on daily injury rates (continued)

	Negative binomial model	*Poisson model*
Pearson Chi-Square (X^2)	378.840	378.859
Degrees of freedom (df)	621	621
X^2/ df	0.610	0.610
AIC (Akaike Inf. Crit.)	1710.998	1708.986
BIC (Bayesian Inf. Crit.)	1728.742	1722.294
Log likelihood	-851.499	-851.493

Note: *p < 0.1; **p < 0.05; ***p < 0.001

Abbreviations: IRR, incidence rate ratio; 95%-CI, 95% confidence interval

4.5.1 Average elevation

The model estimation showed a negative influence on injury risk in both models, indicating increasing average elevation makes it less likely to experience an injury. However, these reverse relationships were not significant.

4.5.2 Average slope

The coefficient of the average slope being positive demonstrates increasing the average slope increases the likelihood of experiencing an injury. However, these relationships were not significant.

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Chapter 5 Discussion and implementations

5.1 Possible illness

Partially, our research questions were interested in examining the epidemiology of illness cases to better understand the characteristics of victims and identify particularly high-risk groups. According to the current study in XNEA, the illness rate decreased over the study period except in the final year. The highest rate we observed in XNEA was in 2012, with 0.049 incidents per 1000 person-days, and the rate was lower in the final year, at 0.023 per 1000 person-days. In terms of risk assessment (Haddock, 2013), the difference in people, equipment, and environmental factors between XNEA and other study sites may contribute to the large difference in illness rates. The difference in participant characteristics and environmental settings may play a crucial role in risk exposure. The decreasing rate may be caused by the risk management process that has continually responded to incidents encountered onsite over time. The strategies of risk management such as raising risk awareness (e.g., using signage to notify visitor of risks), minimizing interpersonal risk (e.g., limiting the number of visitors), or eliminating risks to tourists (e.g., closing dangerous routes and remodeling facilities) were undertaken by XNEA. Moreover, an electric golf cart enables a paid transportation service to people with mobility impairments, including some elderly, pregnant, and adolescent visitors, which could decrease illnesses experienced. These potentially vulnerable people can enjoy natural environment in a convenient manner without creating high levels of pollution. Another potential factor continually helping to lower risk and incidents in outdoor recreation activities is technology advancement. Technologies have been rapidly blended into the outdoors for comfort, safety, protection, food preparation, water storage, navigation, and communication. Currently,

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various technologies developed for outdoor use range from simple tools such as paper maps to high-technology equipment such as global positioning system navigation; participants can select to use these tools according to their preferences (Dickson & Gray, 2012). A smartphone is an example of modern communication technologies that providing many survival advantages in many outdoor recreation areas including XNEA. Because XNEA is in mobile coverage areas, every smartphone feature such as weather forecasting, Global positioning system (GPS), social media, map, area information, phone are fully functional and easily accessible for every user onsite.

5.2 Effect of human factors

Notably, the illness frequency increased in the final year from 21 to 51 (see Table 5.1). To find out the reason of this increasing, therefore, we divided the frequency by age group and observed that the illness numbers increased considerably in the 40–50 years (3 to 13) and ≥60 years (13 to 32) groups. It should also be noted the number of illness cases increased markedly in the ≥60 years age group. We further consulted site managers, and they indicated that the increasing number of senior visitors (from 553,240 to 695,494 in the sixth year) may be the reason illness frequency increased. Further analysis (Figure 4.3) showed that ≥60 years group is still the highest for the six most common symptoms. Thus, age appears to be a crucial factor in visitor risk management.

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Table 5.1 Number of visitors encountering illness by age group

Years	*Illness number (people)*					
	Total	*≤ 17 years*	*18-39 years*	*40-59 years*	*≥60 years*	*Unknown*
1st year	83	25	8	12	28	10
2nd year	47	16	0	18	12	1
3rd year	39	1	7	11	17	3
4th year	35	3	1	5	24	2
5th year	21	3	0	3	13	2
6th year	51	1	1	13	32	4
Total	276	49	17	62	126	22

The risk of encountering illness increased with advancing age (Martínez-Caballero & Sierra Quintana, 2019). Older adults visiting XNEA (≥60 years) were the most vulnerable group to illness, whereas young adults (18–39 years) were the least vulnerable. This finding is consistent with that of other studies that many tourists who travel to the wilderness or participate in adventurous tourism are older adults who are vulnerable to illness (George Washington University & Adventure Travel Trade Association, 2013; Greuters et al., 2009; Martínez-Caballero & Sierra Quintana, 2019). The reasons of susceptibility in this group may be their physical and neurological impairment, particularly their preexisting medical conditions (Ramos-Sesma et al., 2018). For instance, a study on hiking activity in Nepal demonstrated that one-third of tourists participated with a medical problem, and older trekkers were prone to using medication to relieve illnesses encountered in the field (Keyes et al., 2016). Furthermore, to implement appropriate precautions and preparation, understanding chronic problems that may worsen during a journey is required by outdoor recreation managers and elderly travelers. Managers should provide sufficient information to the public regarding risks, and older visitors should comply with health recommendations both before and during the activity.

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In addition to elderly travelers, children (≤17 years) were a notable group. Cases of illness in the pediatric group were fewer than those in the middle-aged group (40–59 years) but were nearly three times those in the young adults group (18–39 years). Hence, children and adolescents are vulnerable to medical problems in the wilderness (Angert & Schaff, 2010; Shaw et al., 2014). However, as presented in Table 4.2, the number of people who experienced each illness varied from 2 for rashes to 132 for dizziness. Because of the small sample size, the frequencies of some symptoms may be misinterpreted from a percentage distribution. To prevent this problem, we applied the n = 30 rule (Kwak & Kim, 2017) and present only six main illnesses that had a frequency of at least 30 in Figure 4.3: dizziness, respiratory problems, nausea or vomiting, chest pain or chest tightness, weakness, and syncope. Furthermore, the pediatric population was more likely to encounter respiratory problems than other medical problems (Thomsen et al., 2005).

This study examined the relationship between sex and illnesses encountered. Although female patients outnumbered male patients, significant differences were absent for all symptoms except syncope, to which male participants were more susceptible than female participants (Figure 4.4). Moreover, syncope is more common in men than in women during outdoor activities (Forrester & Holstege, 2009; Martínez-Caballero & Sierra Quintana, 2019). Our study provided empirical evidence of the significant relationship between sex and syncope development in the current context.

People who experienced illnesses during outdoor activities were hypothesized to have encountered the illness because of a preexisting medical condition. This study tested and partly supported this assumption. Visitors with hypertension may develop dizziness (Marks, 2017), respiratory problems (M. G. Khan, 2006), or syncope (Moon

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& Schaffer, 2011). Visitors with diabetes may develop associated weakness (Auerbach, 2015b). Cardiac-related problems may be connected with chest pain or chest tightness (Auerbach, 2015b). Specifically, participants with high blood pressure had a greater risk of dizziness, respiratory problems, and syncope than other visitors did; those who had diabetes were susceptible to weakness; and visitors with a cardiac-related problem were vulnerable to have chest pain or tightness. These findings are consistent with those of other studies that found that many elderly tourists had these common diseases when traveling in natural areas (Keyes et al., 2016; Martínez-Caballero & Sierra Quintana, 2019), and the symptoms observed among XNEA visitors were also noted in other articles (Forrester & Holstege, 2009; Heggie, 2006b; McIntosh et al., 2007). Moreover, half of the six most common medical problems, namely chest pain, syncope, and dizziness, were among the six most frequently encountered illnesses between 2001 and 2010 in US National Parks (Rickard, 2012). However, these comparable findings did not confirm the link between tourists' medical history and symptoms experienced in outdoor recreation settings. As a result, our research can contribute more understanding and confirm the connection between outdoor visitors' preexisting medical problems and their illnesses encountered. On the other hand, some of the significant associations between preexisting medical conditions and encountered illness were lacking in our research while have been mentioned in some literatures. For example, high blood pressure symptoms may encompass nausea or vomiting (Marks, 2017). However, we did not see a significant relationship between high blood pressure and nausea or vomiting. Such variation in patient symptoms may be due to visitor characteristics, such as their fitness, and external factors, such as ambient temperature. Variation is related to not only physical condition but also psychological state, both of which influence participant safety. Alterations in mood, anxiety, fear, experience, knowledge of the

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situation, or confidence can lead to a negative outcome (Haddock, 2013). The mismatch between residual and perceived risk is a cause of illness in nature-based tourism (Heggie & Heggie, 2004). External factors can introduce symptoms in people with preexisting conditions. Hence, more studies are warranted to evaluate the effect and influence of these risk factors. This research fills the gap and provides a clear understanding of participants' characteristics in relation to outdoor safety management. This finding can raise awareness among people regarding how their medical history can be a limitation. Both visitors and management teams should understand symptoms and corresponding medical aid to act appropriately.

5.3 Managerial implications based on human factors

Destination managers can implement the information detailed in our findings and respond to risks with appropriate control measures. Because of the low illness rate, our control measure recommendation to XNEA is transferring some of the risk. We recommend that XNEA reduce the incident responsibility of the organization by using effective communication. An effective communication approach for risk management in forest recreation is referred to as the deficit model (Skaros, 1998). This model assumes that all participants arrive at the site with knowledge deficits, and everyone is treated equally by sending messages from specific experts in one-way communication (University of Leicester Department of Criminology, 2005). Statistics of illnesses encountered should be presented with precautions regarding the symptoms that visitors may experience that are related to preexisting medical diseases. Various techniques can be used to communicate to potential tourists, such as webpage, videos, educational activities, photographs, or safety signs. These suggestions are based on the case of XNEA, where the incident rate was found to be relatively low and related to the medical

doi:10.6342/NTU202103140

histories of tourists who understand their conditions before visiting. Therefore, tourists may be aware of their well-being, but other areas with higher incident rates may consider screening participants with preexisting medical conditions or limiting access.

Risk management suggests that identifying risk factors regarding to whom, where, and how such incidents occur can minimize losses in outdoor recreation (Barton, 2007; Shanmugam & Maffulli, 2008). This research identified and analyzed the risk as well as provided risk management approaches in the context of forest recreation, particularly from a medical history perspective. Managers of forest recreation destinations can identify illnesses that visitors have encountered and their connection with preexisting medical conditions. These findings can contribute to reducing illness risk in outdoor activities and enhancing the ability of visitors and park staff to assess and prepare for illness incidents based on medical history as well as personal characteristics.

5.4 Limitations and future research based on human factors

There are some limitations in this finding. This study does not incorporate information from any environment except for the one we explicitly studied, so the results may not be applicable to other forest recreation areas. Our finding and research implementation are made from popular outdoor activities most tourists can complete, such as walking, hiking, and picnicking, in a well-managed forest recreation area. Studying other activities or settings may provide varying conclusions and further exploring the relationship between environmental factors and preexisting health conditions or disorders of tourists which may increase the likelihood of experiencing illness is required for an effective risk prevention program.

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5.5 Possible physical injury

In part, our research questions were interested in examining the epidemiology of visitor injury cases to comprehend the characteristics of victims and illustrate especially high-risk environmental condition. A retrospective analysis demonstrates a decreasing trend of injuries experienced throughout the six-year period of the study. This result was consistent with other reports in other settings of the world, such as the United States and New Zealand (e.g., (Brown, 1998; McIntosh et al., 2007; Stanford et al., 2017)). The decrease in injury rate was possibly the result of a spatial risk management approach implemented locally as well as outdoor recreation support technologies (Dickson & Gray, 2012). In other words, raising the risk awareness of recreationists by using signage, limiting the number of visitors, and closing hazardous locations, as well as by providing an e-shuttle service, were implemented to enhance visitor safety in recent years at XNEA. Injuries most often involved female patients (59.6%) at older age (≥ 60 y), and this is not in line with other studies (e.g., (Anderson et al., 2009; Ela, 2004; Heggie, 2005; Heggie & Heggie, 2008; Welter et al., 2015; Wild, 2008)). However, Slips, Trips, and Falls were the major injury type and the lower extremity was the popular anatomic region of injury, and these are consistent with earlier findings (e.g., (Bentley et al., 2004; Ela, 2004; Heggie & Heggie, 2004; Welter et al., 2015)). The injury type profile shows the factor introducing the injury, such as slips/trips/falls, in addition to human concerns, such as lacking physical fitness, or environmental concerns, such as animal-related problems. However, apparently the largest part of injury types were slips/trips/falls, and these injuries are associated with soft tissue injuries (Leemon, 2008). Together with the whole tourist's profile, slips, trips, and falls and the tourist's age seem to be connected together. In other words, those of increased age are more

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often to encounter slips, trips, or falls and they are more likely exposed to soft tissue injury when they do (Nevitt et al., 1991). The effects of aging initiate many harms, such as gait and balance disorders (Salzman & American Academy of Family Physicians., 2011), visual impairment (Muñoz et al., 2000), loss of skeletal muscle endurance (Goodpaster et al., 2006) and musculoskeletal pain (Cuevas-Trisan, 2019) and, all of which increase the likelihood of falls in elderly people (Cuevas-Trisan, 2019). In addition, a prior report summarized that people who have had a previous experience of a fall are more prone to fall again in the future (Ganz et al., 2007). However, there was no testing confirming the effect of these concerns for participants in an outdoor recreation site. Hence, medical history, physical health, and previous fall experience should be gathered from patients and the relationship to injuries experienced should be further investigate in a nature tourism condition.

5.6 Effect of local weather condition

Our finding revealed that the injury rate of visitors was positively related to average temperature, relative humidity, and rain condition. This result fills the lack of weather and injury rate relationships noted in a previous research (e.g. (Gstaettner, Kobryn, et al., 2019). Gstaettner, kobryn, et al. (2019) noted how deficient information on weather conditions were preventing any clear inferences from being drawn to understand why the risk of injury per park visit was higher in certain periods of the year in natural environment. In addition, our six years of data show the clear tendency that injury rate is greatest during summer when the average temperature, relative humidity, and the number of rainy days, too, are higher (Table 5.2).

doi:10.6342/NTU202103140

Table 5.2 Injury rates between July 2012 to June 2018, by season

	Injury rate (per 1000 people)	*Average Temperature (°C)*	*Relative humidity (%)*	*Rain (day)*
Autumn	0.0857	18.91	80.83	15.33
Spring	0.0705	17.16	80.21	27.17
Summer	0.1005	21.15	83.59	40.33
Winter	0.0741	13.23	75.77	17.17

5.7 Effect of topography

Poisson and the NB model were applied for forecasting injury risk with the topographic variables, average elevation and slope. The consequence of model fitting showed neither average elevation nor average slope are significant for the injury rate. The result of this reverse relation was not consistent with the general opinion from prior reports that viewed both elevation and slope to be sources of risk in outdoor recreation (e.g., (Bentley et al., 2006; Gstaettner et al., 2018; Gstaettner, Kobryn, et al., 2019; Heggie, 2006a; Jones & Yamamoto, 2016; Wang et al., 2010)). In line with the literature, we expected high elevation and steep slope to contribute to injury rate; however, that is not the case in the present research. Two plausible reasons for this inconsistency are unequal visitor influx in XNEA and fatigue accumulation. From the investigation (Figure 4.8, 4.9, & 4.10), significant injury cases in XNEA were discovered in or nearby administrative facilities (i.e. ecology center, parking lots, and administration buildings) and popular tourist spots (i.e. University Pond and Meadow-outdoor Performance Amphitheater) which are situated at lower altitudes and on flatter ground. The occurrence of these injury cases may have arisen because of greater tourist numbers in these areas. Specifically, tourists can travel freely over the designated trail network and some popular tourist spots attract a greater number of them than other

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spots, resulting in the issue of unequal injury exposure level at the study area. Moreover, some visitors encountered injures while returning to the flat area due to exhaustion after their extensive walks and descending from an area at higher elevation and with a greater slope. With more injured cases found in the low elevation and flat surface, the results demonstrate elevation and slope in our study area to not have a statistically significant relation in the injury risk model.

5.8 Managerial implications based on environmental factors

To support proactive visitor risk management, this dissertation proposes management implications connected with our research results. As suggested by Eagles (2002), outdoor managers need to recognize both visitor characteristics and the factors that lead to incidents. Our study promotes these two aspects of management based on environmental factors. This epidemiological study of injuries presents data that can help XNEA to know where injuries occur most frequency and which are the most vulnerable groups. The highest-risk group was senior travelers, with slips, trips, and falls as the main problems. Increasing this high-risk group's physical risk awareness by applying an effective communication approach may assist future recreationists evaluate their fitness level and readiness for a trail. Further, organizations have the information regarding injury hot zones and, accordingly, can apply risk prevention tactics, such as posting a map and sign at trailheads with injury hot zones, or limiting tourist numbers at the injury hot zones. Moreover, as noted by Jeuring & Becken (2013), accurate and accessible information about weather risk is necessary for tourists' preparations and adjustments to the setting's weather conditions. Visitors can react to the information by changing their expectations, attitudes, behaviors, and clothing (Dickson & Gray, 2012). Hence, the forest practitioners should support information regarding prior incidents that

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happened at the destination and provide warning to participants so that participants are aware and can prepare themselves properly for the weather. For instance, wearing suitable clothing, especially well-fitting clothes and nonslip shoes, is essential for walking in natural areas, particularly during the day, with hot weather, high humidity, and often rain, especially during summer time when the injury rate is highest. Additionally, with high humidity year-round and temperatures ranging from hot to cold at XNEA, the path can become wet and slippery because of water and green growth accumulation. Therefore, keeping pathways, trails, and infrastructure free from water and slippery growth is suggested for outdoor practitioners to prevent slipping. Other suggestions include building barriers, limiting activity during certain seasons, and installing on-site signage.

5.9 Limitations and future research based on environmental factors

Some limitations in this finding need to be noted. Firstly, the implementation of the findings is limited merely to common recreation activities without any skill requirement for participation, so merely hiking in designated trails, picnicking, and walking in the forest environment. Moreover, this research was studied in Taiwan, which has tropical and subtropical weather. Weather differs in other parts of the world. Thus, this research does not present a range of severe weather patterns or special recreational activities and cannot be extensively generalized for all countries and all activities, but the present findings can explain possible risks for standard outdoor activities that most people can do. Secondly, injury risk is a complex event associated with many factors and not just the variables included in this research. Further injury risk modeling should incorporate more possible contributing variables of injury risk, such as demographic characteristics of tourists, types of land use, trail networks, volume of

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traffic on each trail, trail lengths, and risk exposure in each individual spot, as well as monitoring of updates injury prevention strategies over time so managers can assess their injury prevention programs.

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Chapter 6 Overall conclusion

Inevitably, participating in forest recreation activities sometimes involves risk. Understanding tourists' prior incidents is crucial in order for outdoor practitioners to identify the origins of visitor risk and to reasonably select appropriate manners to minimize the rate of incidents in wildland recreation. Minimal study has examined the relationship between tourist medical conditions and medical problems encountered in the context of forest recreation. Further, limited study has established the association between tourist injury encountered and environmental condition factors in the forest recreation setting. Therefore, the association between preexisting medical condition to illness encountered as well as the relationship between average air temperature, relative humidity, rain condition, elevation, and slope to injury rate were investigated providing the inclusive approach to understand the connection of human factors, environmental factors, and incident in the forest context.

In this dissertation, we applied epidemiology to incident data in the selected nature-based recreation destination of Taiwan, Xitou Nature Education Area, from the period of July 2012 to June 2018, providing facts of illnesses and injuries encountered in terms of frequency and distribution, which can help to identify susceptible groups and dangerous locations. We examined the emergency medical records of incident and environment at the scene of incident along with preexisting medical condition, weather, and topography in a Taiwanese forest recreation area and explored the relationships.

This dissertation concluded that preexisting medical conditions pose an inherent risk to participants of outdoor recreation activities. The results highlight the significance of population factors in ensuring safety in forest recreation risk management. Further,

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this dissertation provided evidence for the positive association between injury rates and weather condition covariates, namely average temperature, relative humidity, and rain condition. This dissertation also demonstrated that the injury rates of visitors are not related with topographical variables regarding average elevation and average slope.

The main contribution of this dissertation lies in the development of proactive visitor risk management based on etiological analysis. The approaches applied in this study did not only provide the conventional descriptive explanation of incidents or risks associated with settings and activities but also advance the better insight of factors resulting in illness and injury that would benefit developing informative-driven management for outdoor recreation. Hence, with scientifically valid manners, this dissertation findings explained the significance, likelihood and probable consequence of incidents which made this study goes beyond statistical records and incident count data.

In the management of risk, this dissertation findings can be implemented with the concept of a whole-of-organization approach highlighting the notion that risk management is the responsibility of everyone in an organization both visitors and outdoor managers. The management needs to be planned before and throughout a situation with every participant and risk factors including people, equipment, and environment. In this vein, visitors should estimate their physical fitness, environmental factors and prepare the equipment that may be used appropriately before embarking on a nature expedition. Additionally, outdoor managers should encourage more visitors' awareness of their own physical strength, medical history, an understanding of how these incidents tend to develop by using outdoor safety precautions such as warning signs to warn vulnerable visitors to exercise caution. Moreover, proactive risk management also involves developing programs and activities for users as well as the

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concerning of the equipment used to facilitate activities. Thus, educating visitors in equipment choice, usage and maintenance correctly can help to reduce the risk of incidents.

The findings of this dissertation can be used for outdoor organization to enhance their visitor risk management strategy and incident prevention program including can be helpful for tourists to evaluate the incident risk of their recreational activity based on individual factors, weather and location. Further studies are required to investigate a more casual link between incident encountered and other possible variables apart from, preexisting health condition, weather conditions and topographical features.

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