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Slopeland hazard and respiratory health: The example of Typhoon Morakot in Taiwan

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HIGHLIGHTS

- Pediatric pneumonia in serious bare areas was higher after Typhoon Morakot.
- Pediatric pneumonia should be considered after landslides from disaster.
- The government should monitor the variation of air quality after serious disasters.

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ABSTRACT

Slopeland hazard may not only induce short-term safety problems, but also long-term respiratory health problems due to slow vegetation recovery and particulate air pollution. Typhoon Morakot induced a serious landslide in southern Taiwan on August 7–9, 2009 and produced particulate air pollution (particulate matter less than 10 μm, PM_{10}). Therefore, respiratory health may be affected by Typhoon Morakot's bare land. The main purpose of this study was to determine whether respiratory morbidity is related to Typhoon Morakot's bare land. A study was conducted to determine whether respiratory morbidity is related with Typhoon Morakot. District is geographical unit of analysis in this study. 368 districts were divided into three levels of bare area based on increased percentage of bare area after Typhoon Morakot: non-bare area (increased percentage equal to 0%), mild bare area (increased percentage less than 1%) and serious bare area (increased percentage greater than 1%). Morbidity data were derived from Taiwan National Health Insurance Statistics. The increased prevalence rate of chronic lower respiratory diseases (CLRD) and pneumonia between pre-typhoon (2008) and post-typhoon (2010 and 2014) were analyzed. The population was stratified into three groups: children (0–14 years), adult (15–64 years), and elderly (≥65 years). The results showed that pediatric pneumonia was strongly associated with Typhoon Morakot. Children were the most vulnerable population for pneumonia in serious bare areas after Typhoon Morakot.

1. Introduction

Damage caused by natural disasters such as earthquakes, typhoons and floods have regularly occurred in Taiwan (Lin, Lo, Chou, & Lin, 2004). Climate changes will increase the frequency of storms and other major weather events (Centre for Research on the Epidemiology of Disasters, 2015). This kind of natural disasters always induce slopeland hazard easily and cause life and property safety problems. Therefore, past studies of slopeland hazard focused on disaster mitigation, including landslide risk assessment (e.g. Dai, Lee, & Ngai, 2002; Van Westen, Van Asch, & Soeters, 2006), slopeland hazard warning, hazard monitoring (e.g. Diodato, Petrucci, & Bellocchi, 2012; McCarthy, Graniero, & Rozic, 2008; Yu, Chen, Lin, Lin, Wu & Cheung, 2007), etc.

Vegetation recovery should be considered in slopeland hazard. Slopeland hazard not only induces landslide, but also causes direct damage to surface vegetation. Slow vegetation recovery was observed after serious natural hazards. For example, Jou-Jou Mountain landslide area caused by the 921 Earthquake in Central Taiwan in 1999. After six years of natural vegetation succession, the average vegetation recovery rate at the sites of the landslides reached thirty-six percent (Lin, Chou, & Lin, 2008). The vegetation recovery conditions in the collapsed area are shown to be worse than that in the deposited area due to topsoil removal and the steep slope (Lin et al., 2008). Wenchuan earthquake in China in 2008 is another case. Large areas of bare land and newly triggered landslides are still prevalent in poor vegetation recovery areas, almost 5 years

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after the Wenchuan earthquake (Wang, Yang, Shi, Xu, & Liu, 2014). Therefore, slopeland hazard maybe not only induced short-term safety problems, but also other long-term health problems due to slow vegetation recovery.

Respiratory health problems may be associated with slopeland hazard. Past studies have shown that air pollutions can be minimized or mitigated by vegetation (Escobedo & Nowak, 2009; King, Johnson, Kheirbek, Lu, & Matte, 2014; Leung et al., 2011; Tallis, Taylor, Sinnett, & Freer-Smith, 2011). In contrast, bare land produces sandstorms and particulate air pollution, reducing air quality from damage of slopeland hazards (Lin, Chen, Yu, & Chang, 2014). Researchers have examined the impact of air pollution on human health in different settings. Several studies have suggested particulate air pollution is associated with respiratory diseases in mortality and morbidity (Cheng et al., 2008; Dockery & Pope, 1994; Kanatani et al., 2010; Schwartz, 1994). In addition, children and the elderly experience greater negative effects from particulate air pollution (Schwartz, 1994).

Typhoons, weather-related natural disasters that induce strong winds and heavy precipitation, often cause severe damage in slopeland. In addition, typhoons have often produced serious air pollution in Taiwan. Typhoon Morakot, the most serious typhoon in Taiwan since 1959. In accordance with the intensity category of maximum sustained winds, the intensity of Typhoon Morakot is moderate. Typhoon Morakot made landfall on the east-central coast of Taiwan on August 7. It enveloped Taiwan on August 8 and moved out to sea on the north of Taiwan on August 9 (Central weather bureau in Taiwan, 2016a). Rainfall is the most frequent landslide-triggering factor (Corominas, Moya, & Hürlimann, 2002). Long-lasting and intense rainfall triggered landslides in many regions in southern Taiwan by Typhoon Morakot (Chen, Chang, Lee, & Chiang, 2015; Doo et al., 2011; Lin et al., 2011; Lin et al., 2014). It brought record-breaking rainfalls (maximum 24-h rainfall amounts were more than 1000 mm in 24 h) and exceed the definition of extremely torrential rain (maximum 24-h rainfall amounts were more than 500 mm in 24 h) (Central weather bureau in Taiwan, 2016b). Typhoon Morakot caused serious flooding and landslides in southern Taiwan due to record-breaking rainfalls (Doo et al., 2011; Linet al., 2014). Compared with other typhoons, Typhoon Morakot produced several large landslide areas (Chen, Tsai, Chen, Chiang, & Ho, 2014) and discussed frequently in landslide studies (e.g. Chen et al., 2015; Liu, Wu, Chen, Chiu, & Shih, 2013). The slopeland disaster and huge slopeland disaster also occurred most frequently (National Science and Technology Center for Disaster Reduction, 2016; Soil and Water Conservation Bureau in Taiwan, 2016). The most serious disaster area was Siaolin Village in Kaohsiung County in Taiwan. Typhoon Morakot induced serious landslides and buried entire villages (Fig. 1) (Doo et al., 2011).

Not surprisingly, local dust events increased in southern Taiwan after Typhoon Morakot and produced high concentrations of particulate matter less than 10 μm (PM_{10}) from non-vegetation areas and river floodplains that were destroyed by Typhoon Morakot (Chiu, 2011; Lin et al., 2014). The strong monsoon winds also increased the level of particulate air pollution during the winter (Lin et al., 2014). Typhoon Morakot induced serious particulate air pollution from bare land that could be related with health problems.

Till now, studies of disaster epidemiology have focused on communicable diseases (Watson, Gayer, & Connolly, 2007) and post-traumatic stress disorder (Galea, Nandi, & Vlahov, 2005). Few studies of landscape have reported on the effects of respiratory diseases and bare land after disasters to explore the relationship between long-term health and disaster, especially from a vegetation damage standpoint. Because it is hard to restore non-vegetation areas that have been damaged by landslides in mountainous areas, the impacts of particulate air pollution may be related with longer-term respiratory morbidity after Typhoon Morakot. It is important to consider the long-term health risks of respiratory diseases. The main purpose of this study was to determine whether respiratory morbidity is related to Typhoon Morakot's bare land. To gain more insight into the relation between Typhoon Morakot's bare land and respiratory morbidity, we analyzed this relation separately for different age groups and different levels of bare land. We hypothesized that respiratory morbidity increased from the pre- to post-typhoon years, which we expected to be especially serious bare area.

2. Methods

2.1. Data sources

2.1.1. Bare area data

District is the geographical unit of analysis in this study. A total of 368 districts in Taiwan was studied to determine whether a positive correlation exists between respiratory morbidity and Typhoon Morakot. Landslide inventory map was utilized to determine levels of bare land after Typhoon Morakot. According to Taiwan Geospatial One Stop (2015), the landslide inventory map used Formosat 2 satellite images of Taiwan area from 2005 to 2014 and Formosat-2 automatic image processing system to analyze spatial-temporal variation for bare area in Taiwan. The accuracy of landslide inventory map is 98% (Lin, Liu, Chang, Cheng, & Ko, 2013). Typhoon Morakot hit Taiwan during August 7–9, 2009. The 2009 data only reflected bare land before Typhoon Morakot because satellite images were captured from January to July in landslide inventory map each year. The annual morbidity data of respiratory diseases also must include morbidity of pre-typhoon period (January to July) and morbidity of post-typhoon period (August to December). Therefore, the 2008 data were selected to determine base-line level. Increased percentage of bare area in each district from 2008 to 2010 was calculated using the GIS software (ESRI ArcGIS 9.2).

We divided 368 districts into three levels of bare area based on increased percentage of bare area: non-bare area (increased percentage equal to 0%), mild bare area (increased percentage less than 1%) and serious bare area (increased percentage greater than 1%). Fig. 2 displayed the condition of bare land in serious bare area in 2008 (pre-typhoon) and 2010 (post-typhoon) through screenshot and represented vegetation destruction in serious bare area after Typhoon Morakot. Non-bare area, mild bare area and serious bare area were 246 districts, 97 districts and 25 districts, respectively (Fig. 2). The increased percentage of serious bare area was 1.04–9.93%. No extremely serious earthquakes or other natural disasters caused serious landslides from 2008 to 2012. Serious bare area is also consistent with major disaster area by Typhoon Morakot. Therefore, the increased bare area should be induced by Typhoon Morakot.

2.1.2. Morbidity data

Morbidity data were derived from the Taiwan National Health Insurance Statistics published by Taiwan's Ministry of Health and Welfare in Taiwan (Taiwanese Ministry of Health and Welfare, 2016). The Taiwan National Health Insurance provides a universal health insurance to all citizens, serving a population of 368 districts for the entire Taiwan. The diseases that we analyzed in this study included chronic lower respiratory diseases (CLRD) (ICD-10 code J40-J47) and pneumonia (ICD-10 code J12-J18). CLRD includes chronic bronchitis, emphysema, chronic obstructive pulmonary diseases, asthma, and bronchiectasis. These two clusters of respiratory diseases were among the ten leading causes of death in Taiwan from 2008 to 2012. CLRD and pneumonia have also been demonstrated to correlate with particulate air pollution (Cheng et al., 2008; Kanatani et al., 2010).