Schistosomiasis in Japan

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Schistosomiasis is a water-borne parasitic disease distributed worldwide, and schistosomiasis japonica is prevalent in the People's Republic of China, the Philippines, and a few regions of Indonesia. Although significant achievements have been obtained in these endemic countries, great challenges still exist to reach the elimination of schistosomiasis japonica, as the occurrence of flooding can lead to several adverse consequences on the prevalence of schistosomiasis.

Keywords: Flooding ; Schistosomiasis ; Environmental Health

1. Introduction

Flooding is one of the major natural disasters that has brought tremendous losses to mankind in the last century by disrupting social growth and economic development [1][2][3]. The World Meteorological Organization reported that floods have caused 58,700 deaths and economic losses of nearly USD 115 billion over the past 50 years [4]. In recent decades, flooding occurred more frequently than before due to climate change and urbanization [3]. A study developed an integrated multivariate trend-frequency analysis (IMTFA) approach to assess climate extremes under global warming. A significant wetting and warming trend was found in Central Asia during the period of 1881–2018, and the warming trend significantly affected the intensities and frequencies of extreme precipitations in most regions of Central Asia [5]. In addition, several studies reported increasing trends in flood discharges in western Europe in the past five decades [6], including a 44% increase in the occurrence of extreme flood discharges [7]. Similar trends in the magnitude and frequency of flooding were also found in Brazil [8]. During 1903–2015, a significant fivefold increase in flood frequency in Amazonia is observable, from roughly one flood every 20 years during the first half of the 20th century to one flood every four years from the 2000s onward [9]. A review analyzed the floods in East China during 1984–2010 and reported a statistically significant increase of 77.4% in the flood cases per decade [10]. Although infrastructures have been strengthened in recent years to decrease the impacts of flooding, two catastrophic floods occurred along the Yangtze River basin in China in 2016 and 2020 [11][12]. The flood in 2020 resulted in 142 deaths/missing cases and a direct economic loss of around 116 billion RMB (~16.5 billion USD), though this is much better than the similarly destructive flood in 1998 due to the development construction of large-scale water conservancy projects on the Yangtze River's mainstream and its tributaries [11].

Except deaths and economic losses, flooding can also increase the transmission risk of infectious diseases [13]. After flooding, traumatic injury, exposure to contaminated environment, poor hygiene, inadequate sanitation, and the lack of access to clean water would increase host vulnerability to various communicable diseases, such as bacterial diarrheal illnesses, cholera, hepatitis A virus infections, cryptosporidiosis, vector-borne diseases, and water-borne diseases [2][14][15][16][17][18][19]. Being a water-borne disease, the transmission of schistosomiasis japonica is also affected by flooding from the aspects of human beings, animal hosts, and environmental health [20].

2. The Impact of Flooding on Schistosomiasis japonica in Human Beings

The occurrence of flooding will change the behavior of human beings and increase the intensity of water contact. Residents in rural areas could suffer from worse consequences because mostly they are nearer to the rivers than residents in the cities. Currently, most published studies of the flood-impact on water contact are carried out in China. Therefore, taking evidence from China for example, there are three reasons for the increase in water contact. First, flooding damages the embankments and people who previously live inside the embankments are directly exposed to the large amount of water that may contain schistosome cercariae. In the past 30 years, several catastrophic floods occurred along the Yangtze River basin in China. During the destructive flood in 1991, 14 endemic counties of schistosomiasis japonica in Hubei province were inundated, with more than 200 embankments collapsed and more than nine million of the population exposed to the contaminated waterbody [21]. Second, risk of water contact comes with various specific flood-related activities, such as flood rescue and self-relieved measures [22]. These activities could provide an extra chance of water contact and lead to an extra risk of infection, because people will not take these actions in usual years without flooding. During the flood in 1998 in China, over eight million people were exposed to the flood water [23], and nearly 150,000 soldiers and civilians participated in the flood fighting and rescue [24]. These soldiers and civilians were not supposed to be exposed to the fecal contaminated water in normal and dry years. Third, other human behaviors also change as a result of flooding and the frequency and duration of water contact alter. Evidence revealed that the major pattern of water contact during flooding was daily life contact in adult females, and swimming and paddling in adult males and children under 18 years old [25]. Certain individuals may attend some water-related recreational activities during flooding because the water body is enlarged by flooding. It should be noted that some amusement activities, such as swimming and fishing in the unknown wild open water, will increase infection risk, since flooding could even carry infected snails or cercariae to previous non-endemic areas of schistosomiasis. Thus, under the condition of higher intensity of water contact, the incidence risk of schistosomiasis will rise. Research reported that, compared with the control group, people in the case group of schistosomiasis had a higher frequency, longer accumulating time, and larger body contact surface area of the water contact [25].

In addition to the higher level of water contact, the dwelling environment and sanitation conditions of the local residents in the flood plains can be greatly influenced by flooding, which is also associated with increased infection risk. The damage to water and sanitation infrastructures during flooding may lead to the disruption of sewage disposal, poor standards of hygiene, poor nutrition, and negligible sanitation, which provide suitable conditions for the transmission of infectious diseases [2][26]. The lack of basic hygiene and sanitation and population displacement will also carry out the outbreak of water-borne and vector-borne diseases, such as schistosomiasis [27][28]. Inadequate feces management will lead to the discharge of feces containing schistosome eggs into the environment. Due to the lack of access to clean water, the victims of flooding are more likely to contact the contaminated water with cercariae.

More water contact leads to the increase in the prevalence of schistosomiasis. A study explored that the average number of acute cases in flood years was 2.8 folds higher than in other non-flood years [29]. The acute cases in Anhui [30] and Hubei [31] provinces increased by 61.73% and 43.90%, from 81 and 246 cases in 1997 to 131 and 354 cases in 1998, respectively, after the catastrophic flood in 1998. In addition, increases in the prevalence of schistosomiasis were also observed in Anhui, Hubei, Jiangxi, and Hunan provinces in 1999 after the 1998 flood [30][31][32][33][34][35][36]. Along with the development of the sanitation and health facilities and the improvement of the natural disaster emergency responses, there was no research reporting acute infection cases or cases with positive stool test results after the similar catastrophic flood in China in 2016, but an increasing trend was detected in the positive rate of indirect hemagglutination assay (IHA). The positive IHA rate of local residents in 26 national surveillance sites in Jiangxi province rose from 4.72% in 2016 to 5.58% in 2017 [37]. Similar positive association between rainfall and higher prevalence is also observed in the Visayas, the Philippines, whereas the relationship is negative in Mindanao with different topography [38]. This is a hint that the impact of flooding on the prevalence can be inverse when adjusting the topography factor. Future studies should explore the reasons of association between lower rainfall and higher prevalence in certain areas, which may provide critical evidence for policy makers targeting world-wide elimination of schistosomiasis. Besides, more evidence is needed to fill up the gap to identify the current status of threats of schistosomiasis transmission caused by flooding in the past 20 years.

3. The Impact of Flooding on Schistosomiasis japonica in Animals

Similar to humans, the risk of schistosome infection in animals is on the rise with the occurrence of flooding. There are over 40 mammalian species serving as the reservoir hosts of *S. japonicum*, with bovines being the most important [39]. In flood plains, vegetation may change in terms of community structure, population size and phenology [40]. For domestic animals, they can be attracted by the vegetation on marshlands and riverbanks, because the grass is lush under the effect of flooding. Moreover, flood water can be contaminated by feces carrying eggs, and then the potentially contaminated flood water will invade grazing areas alongside the embankments due to the damage to barns. In the meantime, feces are also more likely to be excreted into flood water in grazing areas. These two factors will together lead to the increase in exposure risk for the animals. Consistent with the trend in human prevalence of schistosomiasis, the prevalence among the cattle in four counties in Hubei province increased about 1.68 folds in 1999 after the catastrophic flood in 1998 [31]. For wild animals, heavy rainfall encourages wild grass production which supports the growing of outdoor wild animal populations, such as rodents, and the flooding forces the animals from their burrows into closer areas with human beings due to the growing population and the losses of previous natural habitats [41]. The potentially infected wild animals will carry the worm to areas where schistosomiasis had been under control or even to previously non-endemic areas, and further expand the scope of the distribution of reservoir hosts. Few studies have focused on the infection of *S. japonicum* in wild animals. Future research could investigate the infection status among wild animals and explore the impacts of flooding on them to fill this gap and provide evidence for developing emergency responses to control schistosomiasis after flooding, although the investigation is fairly tough to carry out. Besides, it is hard to identify the time frame for zoonotic transmission during flooding. More specifically, previously infected animals, especially wild animals which are difficult to manage, could excrete feces into the flood water and the water will become contaminated. Furthermore, the fecal contaminated water will carry the parasite to infect snails and shed cercariae to infect healthy animals which contact the water during flooding. Thus, in response to this reciprocal causation of animal infection and fecal contamination, interventions should focus both on the management of animals and the treatment of the water.

4. The Impact of Flooding on Environmental Health Specifically for *Oncomelania hupensis*

Flooding will change the ecological environment. Water conservancy (dams, river embankments, channels, levees, etc.) and sanitary facilities can be damaged by severe floods. The damage of sanitary facilities may lead to a higher risk of fecal contamination. The main impact of flooding on the environment is the change in the density and distribution of *O. hupensis* since the snail is the crucial link in the life cycle of *S. japonicum* [42]. Without the existence of *O. hupensis*, the transmission of schistosomiasis will be interrupted successfully. This is the reason why snail control is crucial for schistosomiasis elimination [43].

The density of *O. hupensis* could be influenced by flooding, through the impact on development, reproduction, and ability to survive under the condition of submergence [44]. On the short-term individual level, continuous rainfall and the subsequent flooding facilitate the establishment of snail colonies on vegetation [38]. During rainfall and flooding, the egg production of the snails significantly increases, with one female producing on average two eggs in five days [45]. Yang et al. reviewed the data between 1995–2002 in Hunan province of China, and claimed that the annual rainfall, days of daily rainfall greater than 0.1 mm, and the days inundated with water (favorable for 2 to 7 months) were significantly associated with the reproduction of *O. hupensis* [46]. On the long-term population level, there is a trend of the pattern of snail density in certain local snail habitats [47]. Several studies reported that the rate of the frames with living snails fell in the first two years after flooding and then rose quickly from the third year [29][48]. The decrease in the first two years can be explained as due to the considerable deaths of adult snails [49] and the limited capacity of developing and hatching for snail eggs [50] under the condition of submergence. However, some adult snails can survive through a period of natural drowning and young snails developed well under the drowning condition [49]. This may be the reason for the subsequent increasing trend from the third year after flooding. A study reviewed the annual snail survey in Jiangsu province in China from 1998 to 2003 and reported similar trends in the rate of the frames with infected snails, the snail infection rate, and the density of infected snails [48]. This provides an explanation for the higher risk of schistosomiasis transmission with a higher density of total living snails.

The influence is also demonstrated in the active and passive diffusion of the snails for the following expanded snail habitats. When flooding occurs, the snails drown, climb trees, and passively float down rivers [51]. Along with the side-weir flow after the flood discharge, the snails stay in the places where flow velocity is small, such as the vortex areas [52]. New decent potential habitats develop with the mud deposition due to the flood flow and the snails can actively and slowly move to neighboring new habitats. These active and passive dispersals can result in the enlargement of previous snail habitats, the emergence of new snail habitats, and the rebound in previously snail eliminated areas [43]. During the period from 1979 to 2000, the re-emerging and newly discovered snail habitats in the flooding years accounted for up to 5.8% and 10.1% of the total snail habitats in the Yangtze River valley and were 2.6 and 2.7 times larger than the areas in years with normal hydrologic conditions, respectively [29]. After the 2016 catastrophic flood in China, the re-emerging and the newly discovered snail habitat areas in Anhui province were 1375 hm^2 and 1288 hm^2, respectively [53]. It should be noted that snail dispersal often presents as a retardation effect of flooding, since snails in the new habitats may not reproduce to a large amount that could be easily found by snail surveys and surveillance in one or two years after flooding.

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