## Letter to the Editor

# Impacts of Typhoon 'Koppu' on Infectious Diarrhea in Guangdong Province, China*

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**This study aims to quantify the impact of typhoon 'Koppu' on infectious diarrhea in Guangdong, China in 2009. Rate ratios (RRs) were calculated by comparing person-time of infectious diarrhea cases between typhoon period and reference period. RRs of dysentery and other infectious diarrhea increased to a maximum of 1.12 (95% CI, 0.86-1.47), 1.10 (95% CI, 1.00-1.20) on the fifth lag day respectively. Children under 5 years were more vulnerable to infectious diarrhea, especially to other infectious diarrhea [RR: 1.21 (1.07-1.36) *Vs.* 1.03 (0.89-1.82)] after typhoon compared with people aged >5 years when RRs were at maximum. A mildly increased risk of infectious diarrhea was not only observed in great damaged regions, but also in other areas.**

A tropical cyclone is a non-frontal storm system that is characterized by a low pressure center, spiral rain bands and strong winds, and are the most common extreme weather events affecting marine and coastal areas in the tropical ocean[1]. Tropical cyclones can cause lodging of trees and crops, and bring about great economic losses in affected coastal areas. In addition, they can also increase the risk of morbidity and mortality caused by communicable diseases. There were an estimated 412,644 deaths, 290,654 injured, and 466.1 million people affected by tropical cyclone landings between 1980 and 2009[2]. Cholera outbreak, epidemics of leptospirosis and melioidosis were observed following cyclones in the world[3-4]. The relationship between diseases and tropical cyclones was explored by previous studies, but the impact of typhoon on different damaged regions, susceptible population by age and gender to typhoon are unknown. In addition, the quantitative effects of typhoons on health could be different due to the difference in response capacity of disaster in different countries around the world.

'Koppu', landed in 2009, was one of the typhoons which caused the biggest loss in Guangdong Province, China. It passed through 11 cities and resulted in 13 deaths, 6 missing persons, and 2.393 billion yuan (RMB) direct economic losses. This study aims to quantify the impacts of typhoon 'Koppu' in 2009 on infectious diarrhea in Guangdong Province, China.

'Koppu' was a Category 1 typhoon (Saffir-Simpson hurricane scale)[5]. It originated as a tropical depression in the Northwest Pacific (13.9ºN, 129.6ºE) at 0600 UTC (Universal Time Coordinated) on September 11, 2009, and then strengthened to be a typhoon at 1200 UTC on September 14 with the strongest wind speed near the continental shelf of the northern South China Sea. 'Koppu' reached its peak intensity with estimated maximum wind speed of 140 mph near its center on 15 September. It landed at Taishan in western Guangdong Province in the morning, after which its intensity weakened into a severe tropical storm. In view of the impacts of typhoon 'Koppu' on Guangdong Province, our study areas covered the whole province, which includes 21 cities. On September 17, 2009, the Guangdong Office of Flood Control and Drought Relief Headquarters announced that cities with great damages by typhoon 'Koppu' in Guangdong were Jiangmen, Yangjiang, Maoming, Zhanjiang, Yunfu, Zhuhai, Zhongshan, and Zhaoqing. The cities on the typhoon path were covered by seven wind circle of typhoon 'Koppu' (Figure 1).

Daily meteorological data (daily rainfall and wind speed) from August to September in 2009 were collected from the China Meteorological Data

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Sharing Service System. Average daily rainfall and wind speed were calculated for all observatories recorded per city. Daily disease surveillance data on infectious diarrhea from August to September 2009 were obtained from the Chinese National Notifiable Disease Surveillance System (NDSS). The definition of infectious diarrhea according to the NDSS is a group of human diseases that are mainly caused by microbes (including bacteria, parasites, and viruses) and have diarrhea as the typical symptom including cholera, dysentery, typhoid, paratyphoid, and other infectious diarrhea[6]. Other infectious diarrhea is defined as diarrhea except cholera, dysentery, typhoid, and paratyphoid fever, which belong to category C infectious disease according to the National Communicable Disease Control Act of People's Republic of China.

According to the Yearbook of Tropical Cyclone (2009), typhoon 'Koppu' affected Guangdong from September 13 to 16 (Typhoon period). To minimize potential time-varying confounding effects, a near term reference period is necessary, which is of same duration with the same distribution of days of the week (DOW)[7]. Previous studies showed delayed effects of typhoon on infectious diseases was within seven days, and taking the average incubation period into account, we selected two weeks prior to and after the typhoon landing period as reference period, that is: August 30-September 2 (Reference A) and September 27-30 (Reference B), the reference period = [(Reference A + Reference B)/2].

In this study, we assumed that population in Guangdong changed little within a season, thus person-time units in denominators of the two rates were equivalent. This allowed us to calculate the rate ratio (RRs) between the number of reported cases during typhoon period (a) and number during reference period (b). Formula used for RR was 'RR=a/b', and 95% confidence level (CI) was calculated as: '95% CI of RR=exp(95% CI of Ln(RR)=exp[lnRR±1.96× $\sqrt{(\frac{1}{a}+\frac{1}{b})}$ ][8]. A total of 10 days delay effect was allowed (a delay of 0 means the exact days of typhoon period). We divided disease cases into different subgroups such as age categories, gender, urfban/rural areas, whether located along the typhoon path and whether greatly damaged by typhoon. And RR was used to test the effect of typhoon on different subgroups.

The wind speed and precipitation in the typhoon period were both significantly higher than those in the reference period (data not shown). No new case of cholera was recorded during typhoon period in our study. A few increased number of dysentery and other infectious diarrhea were observed following typhoon 'Koppu'. RR of dysentery and other infectious diarrhea increased to a maximum of 1.12 (95% CI, 0.86-1.47), 1.10 (95% CI, 1.00-1.20) on the fifth lag day respectively. Figure 2 showed that there were lag effects of typhoon 'Koppu' on infectious diarrhea. Unlike death and injury, lag periods exist from exposure to onset of infectious diseases. Hereby, the lag effect could be interpreted as exposure effect on a single day is spread over several

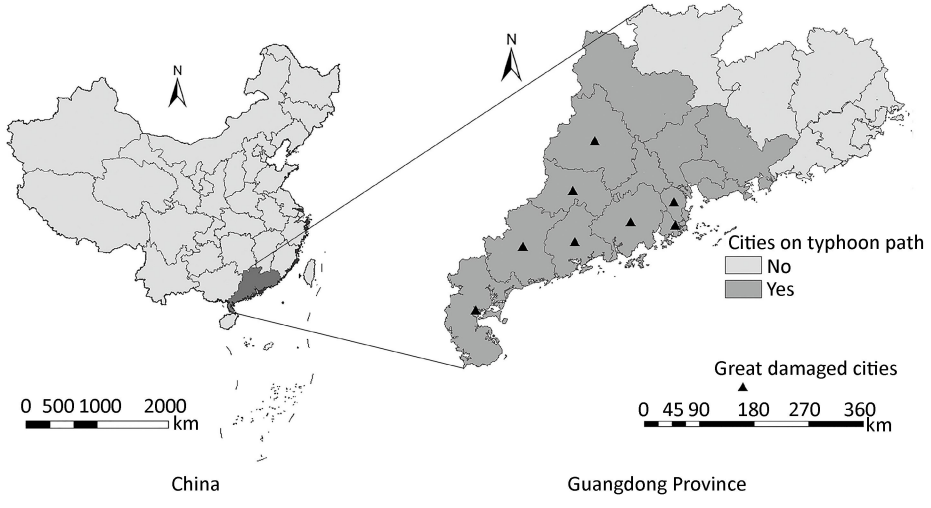


**Figure 1.** Cities influenced by typhoon 'Koppu' in Guangdong Province China.

subsequent days. The duration of the effect period is usually assumed to be that when the rate ratios are at maximum[9].

We also evaluated delayed effects of 'Koppu' between different age categories, gender, urban/rural areas, whether located along the typhoon path and whether cities were reported of great damaged (Table 1). When ratios were at maximum, children under 5 years were more vulnerable to infectious diarrhea, especially to other

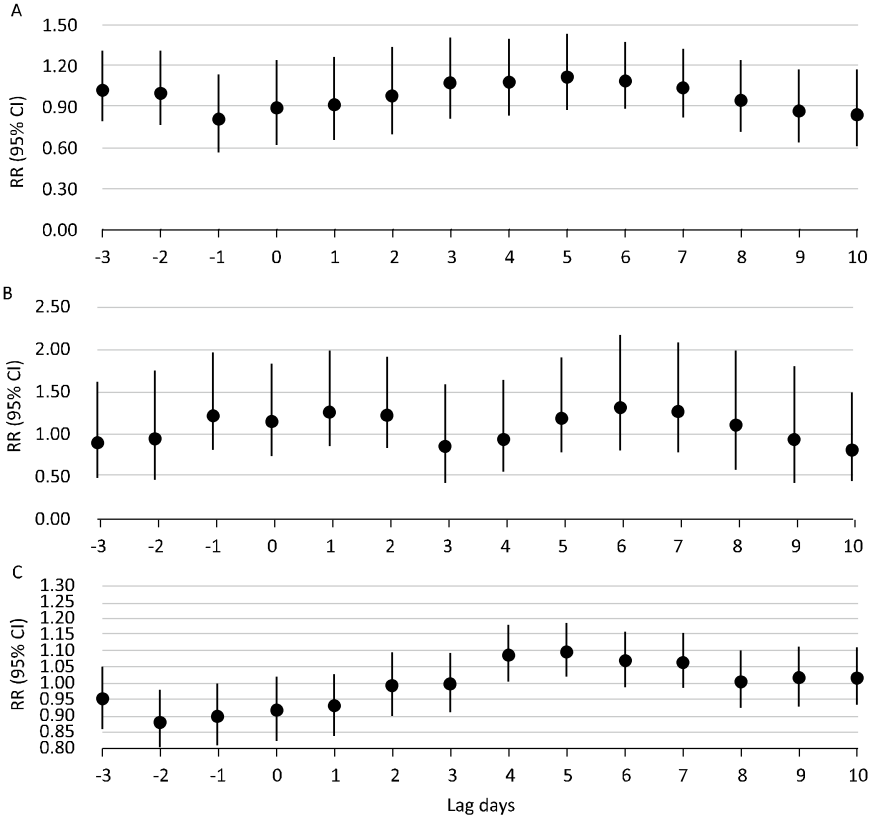


**Figure 2.** Delayed effects of typhoon 'Koppu' on dysentery (A), para/typhoid fever (B), and other infectious diarrhea (C).

**Table 1.** Delayed Effects of Typhoon 'Koppu' on Infectious Diarrhea in Guangdong, China

| Items | Dysentery | | | Para/typhoid Fever | | | Other Infectious Diarrhea | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lag day | Case number | RR (95% CI) | Lag day | Case number | RR (95% CI) | Lag day | Case number | RR (95% CI) |
| Age (years) | | | | | | | | | |
| ≤5 | 5 | 57 | 1.19 (0.81-1.74) | 2 | 6 | 1.50 (0.42-5.32) | 4 | 622 | 1.21 (1.07-1.36) |
| >5 | 4 | 57 | 1.10 (0.75-1.60) | 6 | 27 | 1.29 (0.73-2.27) | 7 | 394 | 1.03 (0.89-1.82) |
| Gender | | | | | | | | | |
| Male | 6 | 71 | 1.31 (0.92-1.87) | 2 | 18 | 1.80 (0.83-3.90) | 5 | 587 | 1.14 (1.02-1.29) |
| Female | 5 | 43 | 0.95 (0.62-1.43) | 7 | 21 | 1.45 (0.74-2.83) | 7 | 402 | 1.05 (0.91-1.20) |
| Urban/rural areas | | | | | | | | | |
| Urban | 5 | 96 | 1.22 (0.91-1.64) | 1 | 24 | 1.45 (0.78-2.72) | 5 | 635 | 1.04 (0.93-1.16) |
| Rural | 0 | 22 | 1.05 (0.58-1.90) | 7 | 13 | 1.63 (0.67-3.92) | 5 | 351 | 1.23 (1.05-1.44) |
| Cities on typhoon path | | | | | | | | | |
| Yes | 6 | 94 | 1.10 (0.82-1.48) | 6 | 28 | 1.56 (0.86-2.81) | 5 | 833 | 1.10 (1.00-1.21) |
| No | 3 | 19 | 1.36 (0.68-2.71) | 1 | 7 | 1.07 (0.37-3.13) | 2 | 159 | 1.14 (0.90-1.43) |
| Great damage regions | | | | | | | | | |
| Yes | 6 | 22 | 1.26 (0.67-2.36) | 3 | 22 | 3.67 (1.49-9.04) | 7 | 457 | 1.09 (0.97-1.23) |
| No | 5 | 92 | 1.12 (0.83-1.51) | 4 | 32 | 1.73 (0.98-3.06) | 4 | 542 | 1.14 (0.99-1.30) |

infectious diarrhea (RR=1.21, 95% CI, 1.07-1.36) after typhoon compared with people aged >5 years. In 2012, Sun LM, et al. reported children under 5 years of age belonged to high-risk group for diarrheal disease in Guangdong in 2012 with the morbidity of 1454.5/ 10 million[10]. In addition, the category of other infectious diarrhea includes all kinds of infectious diarrhea results from bacteria, virus and parasite, different causal mechanisms for each disease category may have influenced the result.

The floating population of Guangdong province is the largest in China, which accounts for nearly 30% of the entire province population. In addition, most of them were concentrated in urban areas and were with low educational level. Only poor sanitation infrastructure was accessible to them, which may be easily damaged during typhoon period. It is well known that dysentery is spread from person to person via the oral-feces route. Thus a high risk of dysentery is reasonable. Compared to reference period, the risk of dysentery in rural areas followed typhoon is higher. The absence of prevention measures and awareness may be a reason.

A mildly increased risk of infectious diarrhea was not only observed in great damaged regions, but also in other areas. Similar results were also found in cities on typhoon path. Typhoon 'Koppu', accompanied by heavy rain and strong winds, caused great loss especially in cities of great damaged where many buildings and infrastructure were destroyed. People of these areas were evacuated to safe areas ahead of time. The government may pay more attention to the evacuees and ensure their availability of clean water and high quality of health service to reduce occurrence and transmission of diseases. Other areas may reported the occurrence of infectious diarrhea because of absence of prevention measures. Hence, not only do disaster regions and cities on typhoon path need attention but also other cities need to be considered when developing prevention strategies and measures after typhoon landfalls.

There are some limitations in the study. Firstly, this study was preliminary and exploratory because we only studied one single typhoon with no comparison with other typhoons of different intensities and durations. Secondly, since the analysis was conducted using only disease data, we could not rule out possibility of confounding effects, such as cross-border migration, patients unavailable to doctors due to disruption of transportation systems. Thirdly, results may be under- or overestimated by selecting an inappropriate baseline. However, the effect of days of the week and seasonality were taken into account in selecting reference period.

In summary, our study found that typhoon 'Koppu' increased risk of dysentery and other infectious diarrhea morbidity in Guangdong Province, China. Different infectious diarrhea had different lag effect after typhoon 'Koppu'. Though the risk of infectious diarrhea reported may not significantly increased, immediate and targeted prevention and control measures should still be developed to prevent a broader spread of infectious diarrhea following typhoon landfalls.

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