Study on tidal characteristics of urban population under COVID-19 based on Baidu Heat map: a case of Tianjin central area

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Summary

This study used BHM(BaiduHeatMap) as high spatial and temporal resolution population data to reflect the tide characteristics of population at high-density urban area during the epidemic period. By comparing with before epidemic, we found the internal differences of residents' behavior patterns and urban space operation between non-epidemic and epidemic period.

KEYWORDS: COVID-19; high density area; population diurnal tide; BaiduHeatMap; Tianjin

1. Introduction

Healthy City is a concept proposed in the 1980s and accepted by WHO(Wold Health Organization) to address the hazards and challenges of urbanization to human health(Tsouros, 1995). The outbreak of COVID-19 has greatly exceeded people's expectation of the virus(Chen and Chen, 2020). Governments had to put forward measures of reducing outgoing and home protection to avoid the spread of the epidemic(Snow et al., 2020). In addition to limiting the scope of activities and travel choices of residents, the outbreak has also psychologically changed the residents' demand for non-basic living functions, which is influencing every aspect of daily life in high-density area(Pan et al., 2020).

In this study, taking the central urban area of Tianjin as an example, the daytime-nighttime PTI(population tidal index) was calculated by BHM data, and the diurnal flow of population during urban epidemic was analyzed to characterize the basic living conditions of urban space by Local Morans'I results(Xia et al., 2020). **Table 1** illustrates the results.

Table 1 Types of Local Morans'I results

type	transalation of population flow
HH	Aggregated population outflows, indicating that the daytime population is more than the night population, and these units have agglomeration characteristics in space.
LL	Aggregated population inflows, indicating that the daytime population is less than the night population, and these units have agglomeration characteristics in space.
LH	Local population inflows, indicating that the daily population of the unit is less than that of the night population, but that the unit is surrounded by units with more people at daytime than night.
HL	Local population outflows, indicating that the daily population of the unit is more than that of the night population, but that the unit is surrounded by units with less people at daytime than night.

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2. Data source and methods

BHM is the dataset by grid images provided by BaiduMap(http://map.baidu.com) to measure the crowded. The original image can be divided into 8 density levels according to the color difference. Previous studies have provided reliable quantitative conversion methods for this data(Zeng et al., 2021). In this study, we use the difference between day and night PDI(population density index) (formula 1) to define the PTI (formula 2), which is used as the index of population flow intensity in urban units. And calculate the local Moran index, so as to form the difference results of population tidal types.

$$PDI_{t1\sim t2} = \frac{\sum_{t=t1}^{t2}\left(\frac{\sum_{g=1}^{7} HV_g \times HC_g}{\sum_{g=1}^{7} HC_g}\right)}{t2-t1} \tag{1}$$

$$PTI = PDI_{10\sim16} - PDI_{17\sim22} \tag{2}$$

where, PDI represents average population aggregation index from t1 to t2, HVg represents score of heat color g, HCG represents grid count of heat color g.

3. Results

3.1. Differences of population tidal types during before and the epidemic

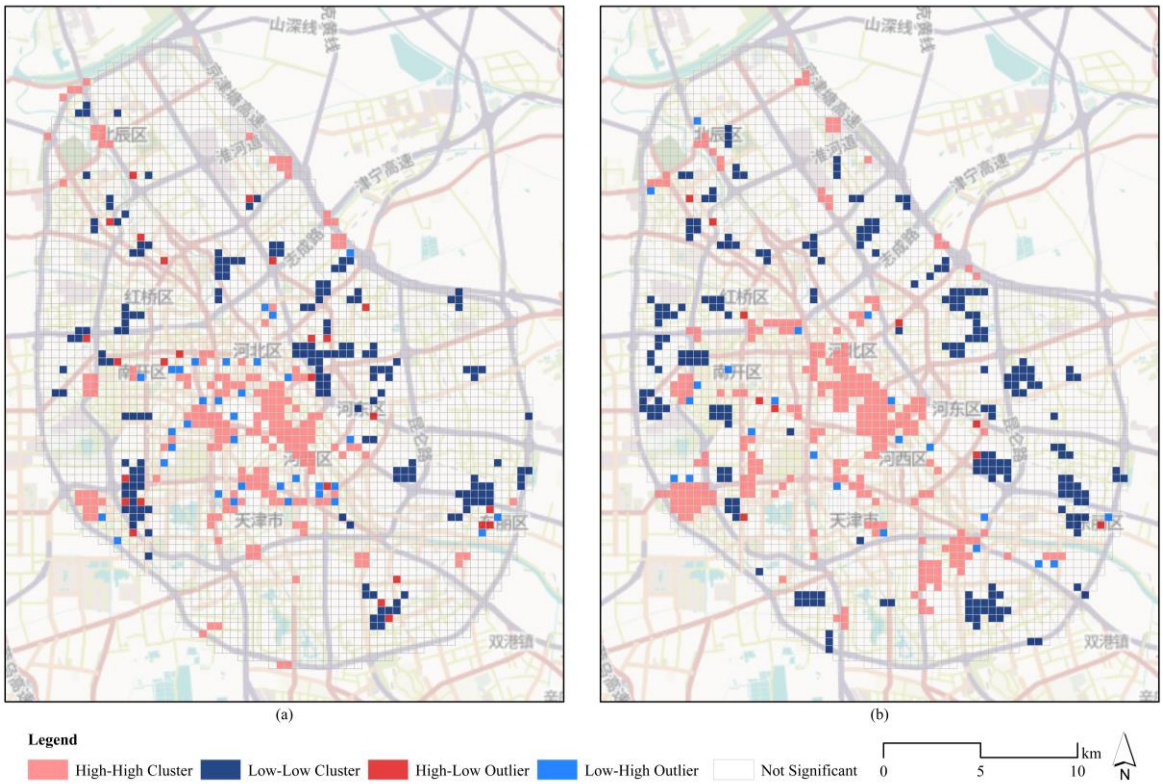

Figure 1 population tidal types distribution(a- epidemic, b-before epidemic）

Figure 1 shows the tidal types of spatial units. It is found that the concentrated population outflow areas (HH type) are concentrated in the southeast and southwest sides of the city center. Southeast area is the concentration of major government departments. The southwest area is the concentrated area of public services such as hospitals. Broken HH-type units, which are far away from the city center, are mainly mixed by main road intersections, housing and public services. The HH type units in the outskirts are the office buildings, and some of the reworked industrial concentrated areas. It is indicating that although the population flow is strictly limited, there is still a space in operation or even overload operation. It ensures the promotion of urban epidemic prevention. LL is defined as the population outflow unit of agglomeration type. It is distributed in the middle distance to the city center area. This kind of spaces have obvious consistency. They are living space with big scale. In addition, transportation is convenient, and houses are built earlier, which don't belong to the newly developed buildings. HL unit is defined as

a local population outflow type, which is generated spatially adjacent to the LL region. They are daytime functional areas around residential space, providing transportation, shopping and public services. LH unit is defined as a local population inflow type, which mainly includes two typical spaces. One is public transport sites around HH unit, the other is the area far from roads and entrances in residential areas.
In order to show the particularity of urban population distribution during the epidemic period, November 28th, 2019 was selected as a comparison. **Figure 1(b)** shows the results. Compared with the various types of spatial units in the epidemic period, the concentrated population outflow(HH) in the central area is continuous. The number of local population inflow(LH) and outflow(HL) units in the study area is small, and results form a trend of migration from the center to the periphery from day to night.

3.2. Differences of patch characteristic between before and the epidemic

Furthermore, the distribution of each tidal type was measured. DC(average distance to city center), TA(total area) and PN(number of patches), AA(average patch area) and LPA(largest patch area) were compared to the pattern differences between bofore-epidemic period and the epidemic period. **Table 2** shows the statistical results.

Table 2 Results of population tidal types distribution

	DC (m)		TA ($*10^4m^2$)		PN		AA ($*10^4m^2$)		LPA ($*10^4m^2$)	
	before	epidem-ic	befo-re	epide-mic	bef-ore	epide-mic	before	epide-mic	before	epide-mic
HH	6892.15	6434.38	4096	3088	52	52	78.77	59.38	1184	752
HL	8264.05	8856.16	160	416	10	25	16.00	16.64	16	32
LH	8404.2	5740.29	352	554	22	32	16.00	17.31	16	32
LL	9807.35	8500.72	3680	2848	56	50	65.71	56.96	304	352

Tianjin is a typical city with a single core, and DC indicate the scope of day and night population flow. DC of HH has little change between before and the epidemic, because of the concentration of administrative functions. DC of LL is reduced by more than 1000m. The population outside 8500m from the city center is more obviously affected. DC of LH type decreases obviously, indicating that LH units are closer to the urban center. It can be speculated that during the epidemic, people won't enjoy leisure and entertainment places near the center after work. HL type's DC slightly increased, but the overall change is not patent.
Comparing the characteristics of each type on patches, TA of HH and LL decreased significantly. The intensity of population flow decreased, and the diurnal tide phenomenon weakened. The HL and LH type spaces increased significantly, by 160 % and 57.39 %, respectively. It indicates that short-range population migration became the main mode of urban operation. The PN of HL and LH type increased, which was also caused by the decrease of population flow radius, resulting in a large number of related units around HH and LL. It is found that the largest patch of HH type is significantly reduced. In the normal period, the largest patch of HH is in the central area of the city, including the agglomeration of government agencies, medical and health facilities, commercial concentration and other contiguous areas. They constitute the largest tidal patch in space. During the epidemic, commercial places stopped, high-density office buildings are close to shutdown, so the central area of population concentration area is separated.

4. Conclusion

From the results above, we found medical resources concentrated areas become the population concentration during the epidemic. The phenomenon of population mobility in the city has undergone fundamental changes. The urban space operation under the epidemic situation provides a new scenario for urban public health security. It's important to the normalization of epidemic prevention.

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