GREEN SPACE AVAILABILITY AND ONSET RISK OF COVID-19 IN HONG KONG: A SPATIAL JUSTICE PERSPECTIVE

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1. INTRODUCTION

As concerns arise about the impacts of urban environments on health outcomes and healthy lifestyles, urban researchers are increasingly investigating the associations between the built environment and public health (Ha et al., 2022, Luo et al., 2022).

Public Green spaces (PGS) offer various ecosystem services to city dwellers. The literature generally endorses the view that exposure to natural environments, especially green spaces is vital, for its evidenced benefits to people's health and well-being both through active participation and as a salutogenic environment (Nutsford et al., 2013) (Spotswood et al., 2021). Besides the distance to the nearest green space as a well-known factor, the health benefits of PGS, which has a lag effect and lasts for years (Wang et al., 2021), are also expected to be influenced by the usage frequency, duration, and intensity (Ha et al., 2022).

The concept of spatial justice refers to the manifestation of the principle of justice in spatial production and the allocation of spatial resources (Soja, 2013). It is also concerned with PGS provision as one of the health resources. There was a groundswell of opinion that adequate access to green spaces is a common good for society that all citizens should equally benefit from. More accessible green spaces should be provided for building healthy cities in post-pandemic societies (Luo et al., 2022), although urban planners struggle to allocate UGS evenly (Jian et al., 2020).

The outbreak of COVID-19 poses an unexpected threat to people's health worldwide. As scientific models have demonstrated the effectiveness of social distancing restrictions on slowing down the transmission (Chen et al., 2022), a set of regulations to limit activities, particularly the free use of PGS, are imposed (Pan et al., 2021).

However, many studies conducted during the pandemic show that inequity in the amount of PGS people can access has the potential to translate into inequities in mental and physical health both during and beyond the pandemic (Spotswood et al., 2021). PGS can provide more benefits to vulnerable groups by offering stronger protective effects. Marginalised groups worldwide may expose to a higher risk of certain diseases than more privileged groups for being excluded from access to PGS, particularly those vulnerable groups who are always labelled with lower income and education levels, age, and gender minorities (Sikorska et al., 2020, Sillman et al., 2022).

On the other hand, maintaining a safe distance is challenging in many outdoor areas, especially in increasingly dense urban environments. For instance, despite the number of PGS visitors being decreased at the beginning of the social-distancing restriction, people were reported to have a higher demand for using PGS during the pandemic due to the unavailability of other activities (Liu and Wang, 2021). It is predicted that the total park visitation may exceed the pre-COVID baseline (Geng et al., 2021).

Meanwhile, as the recent evidence shows that exposure to airborne viruses further arises from human population movements between places, higher accessibility to PGS also corresponds to a higher risk of infection spread as using PGS further increase the opportunity for people to meet face to face (Pan et al., 2021). PGS in this sense might give rise to the number of new cases, and negatively contribute to managing the outbreak of the pandemic by providing chances for people to cluster and spread the disease (Yao et al., 2021).

Eventually, the government needs to release the restrictions to allow citizens to return to "normal" lives. Since the relationship between the availability (i.e., amount and accessibility) of green spaces and covid-19 cases in compact cities remain insufficiently explored (Ha et al., 2022), this research attempts to explore whether PGS with higher availability is linked to higher COVID-19 case rates and whether the PGS access related to COVID-19 case rates is linked to people's socio-demographic characteristics in compact urban environments.

Following this introduction, this paper is divided into four parts. The first part provides a brief account of the PGS visitation during COVID-19, followed by a general discussion of spatial justice with health considerations. We then describe the methods used to answer our research questions. We outlined the patterns of uneven distribution of PGS and explored the

relationships between the availability of PGS and the onset risk of covid-19. The final part presents and concludes our findings, and suggests implications for future studies.

2 LITERATURE REVIEW

2.1 PGS visitation during COVID-19

Researchers have found common ground in terms of the mechanisms through which PGS benefit people's health and well-being, namely restoration, instoration and mitigation (Browning et al., 2022). To elaborate, contact with PGS can potentially reduce exposure to harmful environmental stressors, foster healthy behaviours, and restore capacities such as providing relief for cognitive processes and stress (Rigolon et al., 2021).

Higher proportions of PGS in proximity in the neighbourhood were associated with lower anxiety levels (Nutsford et al., 2013). Chicago Residents reported lower psychological distress levels during the pandemic if their neighbourhoods had many small green spaces that were dispersedly distributed, or if they lived in urban landscapes that had greater distances between forested areas (Ha et al., 2022). Huang et al. (2020) used Tertiary Planning Unit (TPU) as the analytical unit and found a negative association between population density and the risk of COVID-19. The authors suggested that higher green space density could help reduce the risk of COVID-19 transmission.

Under the social-distancing situation, the behaviour of PGS use has changed significantly as the spaces became the only "out-of-home" option (Liu and Wang, 2021). Larson et al. (2022) reported that most of the college students reduced their park use for fear of the COVID-19 virus. Their outdoor recreation activities were also decreased due to structural constraints, park closures, and shifting social norms. Notably, race is claimed to be directly linked to this behaviour. On the other hand, the necessary activities (e.g., walking the dog, outdoor exercise) increased as Pan et al. (2021). Some people raised their park visitation for their desire to be outdoors, to occupy free time, and for health considerations (Larson et al., 2022). In Hong Kong, people visit country parks or go hiking more to relieve stress and anxiety during the pandemic (Ma et al., 2021). The demand for using PGS for outdoor activities increases. However, the relevant policies range from decreased opening times to opening with limited functions reduce the amount of available PGS drastically, raising concerns about its ability to fulfil people's essential physical and mental health needs (Liu and Wang, 2021).

2.2 Spatial justice with health considerations

Spatial justice argues for eliminating plausibly avoidable disparities in spatial-related resources among different social groups. These differences could adversely influence vulnerable groups, either economically, socially or structurally disadvantaged, and lead them to more unfavourable situations (Soja, 2013). Spatial justice in public open space contains five dimensions, namely access and management, sociability and diversity, demand and provision, social stratum and information, and social inclusion (Jian et al., 2020). Pursuing spatial justice with health considerations means devoting efforts to maintaining people's equal opportunity to attain their full health potential, including equal access to available health-promoting resources, such as green spaces (Braveman, 2017, Jian et al., 2021).

PGS tend to matter most in dense areas. People living in these environments are at a higher risk for health and well-being owing to increased air pollution, traffic noise, less available open area, and smaller living spaces (Rigolon et al., 2021). These issues disproportionately affect different segments of the population. As a finding reached by a number of papers, low-earning individuals were more dependent on recreation activities with lower cost, yet, their access to PGS was constrained compared to wealthier people, while the older group suffered more from inequitable distributed PGS because of limited mobility (Rigolon et al., 2021). Although previous evidence has proved that PGS present stronger protective

effects for socially vulnerable groups relative to other populations (Markevych et al., 2017), the epidemic has exacerbated the

unfavourable conditions in low-income areas, which were already facing reduced availability of PGS (Spotswood et al., 2021).

3 METHODOLOGY

We selected Kowloon, Hong Kong as our case study. As one of the world's most densely populated coastal cities, Hong Kong people were reported as "suffering from a lack of urban life" – the PGS provided are far beyond satisfactory in terms of quantity and quality (Jian et al., 2020).

3.1 Dataset and data processing

The COVID-19 case data which covers a time range from 23 January 2020 to 6 February 2022 were obtained from the COVID-19 daily press release[1] published by the Department of Health of Hong Kong. The dataset provides detailed information on all the confirmed cases (e.g., age and the geographical locations recorded during the incubation period). Notably, the government stopped sharing detailed case information from 6 February 2022 due to the high number of new cases per day. The spatial statistical unit (Large Street Block Groups, block) of the 2016 Hong Kong Population Census data was used as the spatial representation proxy in this study. In total, Kowloon consists of more than 500 blocks. The census data contains people's socio-demographic information, such as age composition, gender, and ethnicity. 3D Pedestrian Network data used in this research were published by the Lands Department of Hong Kong. The data of the PGS that was published by the Hong Kong Leisure and Cultural Services Department cover 367 open spaces of 500 square metres or more in Kowloon, including parks, children's playgrounds, and rest gardens.

3.2 PGS availability

In order to calculate the availability of PGS in Kowloon, we divided the spaces into three categories according to their size and service capacities: regional PGS (>5ha), district PGS (1ha-5ha) and local PGS (500m^2-1ha). As the accessibility of PGS is one of the crucial indicators to demonstrate service efficiency, we used the PGS area per capita within the reachable area of each block to indicate the availability of PGS. Network analysis was conducted as the most suitable method for the reachable area calculation because of its merits in accurately estimating actual walking distances (Sikorska et al., 2020). The method considers travel routes rather than using the commonly used fixed-distance buffer or calculating Euclidean distances, which is likely to underestimate the travel time (Huerta, 2022). A walking distance of 1250 metres was assigned to the regional and district PGS and 400 metres to the local PGS. The reachable area of 400 metres corresponds to the commonly acceptable 5-minute walking distance recognised in the literature to reach the local PGS (Schindler et al., 2022). The final calculations yielded PGS availability for all 537 blocks in Kowloon.

3.3 Multiple Regression analysis

Two regression models were used to explore the relationship between onset ratio and PGS availability for each block: the generalised multiple linear regression (GMLR) model and the geographically weighted regression (GWR) model. The dependent variable is the onset ratio of each block, the independent variables are population density and PGS availability. The regression results are divided into nine groups: (a) GMLR for all ages, (b) GMLR for children (< 15 years old), (c) GMLR for the elderly (< 65 years old), (d) GWR for all ages with auto-bandwidth, (e) GWR for children with auto-bandwidth, (f) GWR for the elderly with auto-bandwidth, (g) GWR with self-defined bandwidth (20 neighbours) for all ages, (h) GWR with

[1] https://www.coronavirus.gov.hk

self-defined bandwidth (20 neighbours) for children, and (i) GWR with self-defined bandwidth (20 neighbours) for the elderly.

4 RESULTS

A higher possibility of infection rate of COVID-19 can be observed in economically deprived areas (e.g., Sham Shui Po and Wong Tai Sin). Notably, Sham Shui Po has high onset rate, low medium income, and limited regional PGS availability at the same time (Figure 1). No obvious difference can be observed in terms of the onset ratio for different age groups (Figure 2).

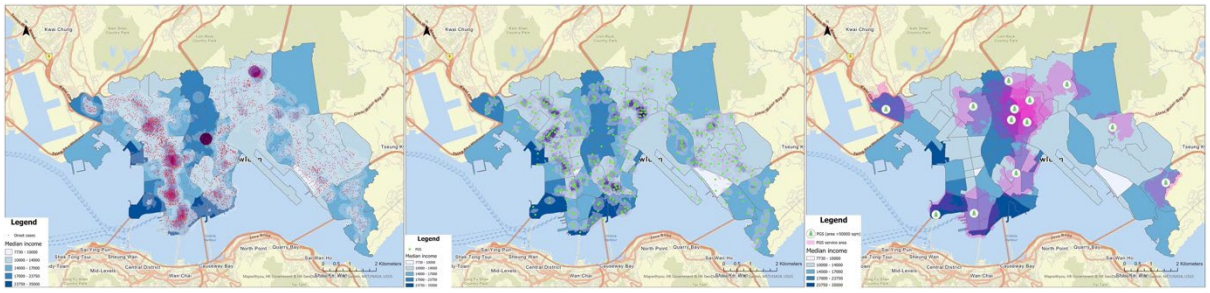

Figure 3 medium income and COVID-19 case density (left); PGS density (middle); and Regional PGS (right).

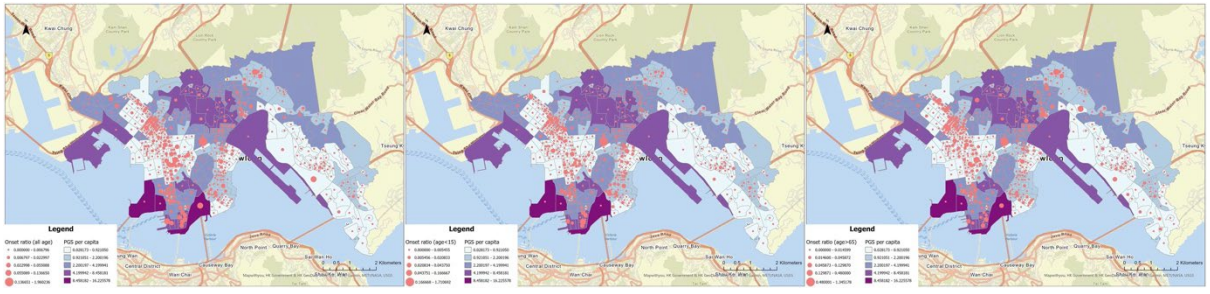

Figure 4 onset ratio for all age groups (left), children (middle), the elderly (right).

At the global scale, the results of the GMLR model indicate that the PGS availability and onset ratio exhibit a positive correlation coefficient close to 0, which can be interpreted as almost uncorrelated (Table 1). The correlation coefficient improves slightly after introducing a GWR model with automatic bandwidth (Table 2). It should be noted that the automatic bandwidths were all around 300 in these three groups (i.e., *d*, *e*, and *f*), which are still close to the global scale. It is likely that the excessive bandwidth is causing the GWR model to approach global regression. After several tests, we set the bandwidth to 20 neighbours as the fit of the model improved significantly (Table 3) (Yao et al., 2021).

Table 1 Multiple regression models results

	a	b	c
Multiple R^2	0.008	0.005	0.001
Adjusted R^2	0.004	0.001	0.001
Coefficient PGS availability	0.001	0.001	0

Coefficient population density	-0.07	-0.004	-0.07
AICc*	-	-	-
Bandwidth	-	-	-

Global scale
*Akaike information criterion

Table 2 Multiple regression models results

	d	***e***	***f***
Multiple R^2	0.04	0.04	0.04
Adjusted R^2	0.007	0.008	0.11
Coefficient PGS availability	-	-	-
Coefficient population density	-	-	-
AICc	-1109	-1225	-1369
Bandwidth	318	286	353

with auto-bandwidth, local scale

Table 3 GWR model with self-defined bandwidth

	g	***h***	***i***
Multiple R^2	0.69	0.68	0.64
Adjusted R^2	0.47	0.46	0.38
AICc	-1220	-1365	-1391
Bandwidth	20	20	20

Bandwidth=20 neighbours

5 DISCUSSIONS AND CONCLUSIONS

Understanding the relationship between the PGS availability and COVID-19 risk for different age groups could offer guidance for authorities to cope with the pandemic. This preliminary study examined the claimed coupled effect of PGS availability on the COVID-19 cases distribution with considerations of age-based social vulnerability in compact urban environments. Using Kowloon, Hong Kong as a case study, we adopted two multiple regression models, namely GMLR and GWR to test the coupled effect at the street block level. The explorative analysis results suggest that in general, at the global scale, there is no significant correlation between COVID-19 prevalence and PGS availability for different age groups. As the existence of such a correlation cannot be completely rejected at the local scale, it is possible that the local PGS availability corresponds to a higher risk of COVID-19 transmission than the district and regional ones as the local PGS are smaller, and people would be harder to maintain proper social distance. However, the role of PGS availability and the mechanism of the process require further evidence.

Socioeconomic vulnerabilities are typically seen as mediating or moderating factors when studying the health-promoting effects of PGS. Surprisingly, our findings are not in consonance with many previous studies that claimed the age-based vulnerable groups such as children and the elderly are likely to benefit more - both physically and psychologically – from PGS in the COVID-19 pandemic (Rigolon et al., 2021). We found no significant correlation between the COVID-19 onset ratio and PGS availability for the elderly and children at both global and local scales. Age-based inequalities do not necessarily exist when it comes to the coupled relationship between PGS availability and COVID-19 cases. However, it is undeniable that PGS can actively interfere with people's ability to fight infection (Spotswood et al., 2021).

Cities are dynamic and complex systems that are influenced by a variety of internal and external factors. Apart from PGS availability that considers PGS area, and 3D pedestrian road network accessibility, several other variables of the built environment could potentially impact disease transmission in dense and compact environments. For example, Huang et al. (2020) identified a spatially heterogeneous relationship between the certain built-environment variables (e.g., land-use diversity) and the risk of COVID-19 transmission in Hong Kong, while Yao et al. (2021) observed a strong correlation between the COVID-19 cases and the road network configuration. The appearance of PGS in the immediate environment does not necessarily link with people's usage and contact. There are many factors that influence people's PGS visitation as mentioned above. The effects of PGS availability are not significant in this study.

The following limitations of this study could help explain our results. First of all is the data uncertainty, as the geographical locations of the confirmed cases provided by the Hong Kong government include several places they have visited during their incubation periods. The accurate place where people get affected cannot be identified.

As highlighted by Huang et al. (2020), different analytical units or case study areas may produce different results. This preliminary study only considered PGS that are larger than 500 m^2 and regarded all PGS as homogenous environment resources. Apart from PGS, HK has many other types of accessible green spaces, including brownfields, public open spaces in private developments, and informal pocket spaces that are constantly used by the elderly who live nearby. Taking into consideration of other factors in the analysis might generate different results.

In the middle and later stages of the epidemic, as cities gradually lift restrictions on mobility, and the large number of confirmed cases that cannot be traced back to their source, we suspect that the urban environment may gradually decouple from the number of confirmed cases and the risk of transmission from the use of PGS will gradually decrease, with the benefit outweighing its risk. These hypotheses warrant further investigation.

Prolonged self-isolation can lead to adverse psychological effects. In the long run, governments worldwide need to strike a balance between allowing PGS and reducing the risk of pandemic transmission. Pathways toward building a healthy city must prioritise the equitable provision of PGS and attach greater importance to the health-promoting effects of PGS.

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