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Dose-response effect of a large-scale greenway intervention on physical activities: The first natural experimental study in China

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ABSTRACT

Although many cross-sectional studies have confirmed the positive associations between greenspaces and physical activity, evidence from natural experiments is scarce, especially for large-scale greenspace interventions. In addition, it is unclear how the physical-activity-related benefits of a greenspace intervention vary with distance from residences to greenspaces. We used a natural experimental approach to explore the impact on physical activity of a large-scale greenway intervention, namely the East Lake greenway, in Wuhan, China. Two waves of survey data (before and after the intervention in 2016 and 2019, respectively) were collected from 1020 participants residing in 52 neighbourhoods at different distances (0–1, 1–2, 2–3, 3–4, and 4–5 km) from the 102-km-long greenway. The results obtained using difference-in-difference models indicated that the greenway intervention had positive effects on both moderate-to-vigorous physical activity (MVPA) and overall physical activity (MET-minutes/week) after controlling for individual and neighbourhood covariates. Furthermore, the physical activity benefits of the greenway intervention were found to decrease with increasing distance between the greenway and the participants' residences. Individuals living closer to this large-scale greenway accrued more substantial physical activity benefits. Our results, together with those of other natural experimental studies, suggest that large-scale greenspace interventions may provide long-term physical activity benefits to residents living in a wide geographic area.

1. Introduction

1.1. Prevalence of physical inactivity

Physical inactivity is the fourth leading cause of death worldwide (Artinian et al., 2010; Forouzanfar et al., 2015), accounting for more than two million deaths annually (Forouzanfar et al., 2016). Inadequate physical activity significantly increases the risk of non-communicable diseases (NCDs), such as coronary heart disease, type II diabetes, and breast and colon cancer (Lee et al., 2012), which are tremendous economic burdens that account for up to 3.0% of total direct healthcare costs (Oldridge, 2008). To reduce the risk of NCDs and alleviate the related healthcare burdens, the American Heart Association recommends that adults should engage in at least 150 min of moderate-to-vigorous physical activity (MVPA) per week (Services, 2008). The World Health Organisation, too, recommends engaging in physical activity in excess of 600 metabolic equivalents (MET) per week, which is the equivalent of 150 min of brisk walking or 75 min of running (World Health Organization, 2012).

Hence, many countries consider encouraging physical activity as a public health priority (Heath et al., 2012). Despite extensive investment in individual interventions and education to change individual behaviours, population-level physical activity has remained relatively constant (Evenson et al., 2005; Hunter et al., 2015). Consequently, researchers and public health officials are exploring the role of built environmental interventions in promoting physical activity because such interventions may have longer-term effects on greater numbers of people (Cohen et al., 2013; P. Craig et al., 2012). In general, residents are more likely to be physically active in dense, compact neighbourhoods with mixed land use (Day, 2016; D. Ding and Gebel, 2012; Forsyth et al., 2007).

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1.2. Greenspace and physical activity

One potential built environmental intervention to improve physical activity is creating pleasant and accessible urban greenspaces, such as parks, tree-lined streets, and greenways (Brown and Cummins, 2013; Clark et al., 2014; Cohen et al., 2013). Exposure to urban greenspaces is positively related to increased physical activity (Akpinar, 2016; N. Chen et al., 2019; Y. Chen et al., 2017; Hunter et al., 2015; Veitch et al., 2012; Zuniga-Teran et al., 2019), reduced sedentary behaviours (Frank et al., 2019), and more active means of transport such as walking and cycling (Burbidge and Goulias, 2009). Exposure to greenspaces may deliver additional health benefits due to reduced air pollution and noise (Conine et al., 2004; Fábos, 2004) and provide opportunities for contact with nature (Chon and Shafer, 2009). However, most of these studies were based on cross-sectional research designs, thus making it difficult to infer any causal relationship between greenspace exposure and increased physical activity (Fábos, 2004; Jang and Kang, 2015; Keith et al., 2018; Lindsey et al., 2008). For example, the cross-sectional research design is often criticised for the residential self-selection bias, meaning that a person with a positive attitude towards physical activity may intentionally choose to live in a neighbourhood next to an urban greenspace to engage in more physical activity (Beenackers et al., 2012; Zang et al., 2019). Hence, the observed association between greenspace and physical activity may be spurious and reflect only personal differences in lifestyle preferences.

1.3. Natural experiments in greenspace-physical activity studies

Compared with cross-sectional research designs, natural experiments have been advocated as a superior research approach by academics and policymakers to understand the health and behavioural impacts of built environmental interventions (Sallis et al., 2009; Veitch et al., 2012). Natural experiments relate to but also differ from full experimental methods such as randomised controlled trials (RCTs). In RCTs, participants are randomly assigned to either a treatment (taking a new drug) or a control group (taking a placebo). Both the participant assignment and treatment implementation are controlled by the researchers. However, unlike RCTs, natural experimental studies are based on naturally occurring events because environmental interventions in public health studies are intrinsically hard to manipulate due to ethical, political, or economic reasons. Consider a hypothetical case in which a new urban park is created. A team of researchers may conduct natural experimental studies to compare any changes in the physical activity levels (before and after the park's creation) of the people living close to the park and those living far away from it. However, neither the implementation of such interventions (creation of the park) nor the participants assigned to the exposed group (those living close to the park) or unexposed group (those living far away from the park) are under the researchers' control. Therefore, natural experimental studies are prone to bias and have limited internal validity compared with RCTs. Nevertheless, as an alternative to RCTs, natural experimental studies can improve the validity of inferences by making the credible assumption that participant assignment is "as if" random (Dunning, 2008, p. 283). In other words, natural experimental studies have higher levels of external validity than tightly controlled RCTs, which often do not reflect the real world. Hence, natural experimental studies can still provide practice-based evidence that is relevant to decision makers (Leatherdale, 2018).

Only a handful of natural experimental studies have explored the effects of greenspace interventions on changes in people's physical activity levels (Burbidge and Goulias, 2009; Evenson et al., 2005; Fitzhugh et al., 2010; Frank et al., 2019; Krizek et al., 2007; Veitch et al., 2012; Stephanie T. West and Shores, 2015). Most such studies have reported that a greenspace intervention has significant and positive effects on the promotion of physical activity (Huston et al., 2003; Merom et al., 2003; Tester and Baker, 2009). Two studies reported no effects (Burbidge and Goulias, 2009; S. T. West and Shores, 2011), probably because the intervention exposure duration was too short (Evenson et al., 2005).

Despite the high-quality evidence obtained from natural experimental studies, little is known about the dose-response effect of greenway interventions. Studies have typically addressed whether greenspace interventions have an impact on nearby residents by comparing the groups living close to and far away from greenspaces (see Hunter et al., 2015 for the review). Hence, the dichotomy of exposed and unexposed groups (for example, using a single distance threshold) makes it challenging to elucidate the dose-response effect of greenspace interventions, that is, changes in the physical activity and health benefits resulting from greenspace interventions change as the distance increases.

As an exception, Frank et al. (2019) examined the physical activity effect of exposure to a retrofitted greenway using multiple distance thresholds (100 m, 200 m, 300 m, 400 m, and 500 m). They found that the physical activity benefits resulting from the greenway declined as the distance from the greenway increased from 100 m to 500 m. However, this study used relatively short distance thresholds (of up to 500 m), probably because the 2-km-long neighbourhood greenway was relatively small. The 500-m threshold may not have been able to capture the entire spectrum of the effects of city-wide greenspace interventions. For example, residents are willing to visit a large greenspace located more than one mile away (Rossi et al., 2015). In the current study, we explored the impact of a large-scale greenway project spread over a 102-km-long route, which is roughly 50 times longer than the route considered in Frank and colleagues' study (Frank et al., 2019). Hence, we used longer distance thresholds. In addition, using different exposure levels to greenspace interventions, measured by multiple distances from the interventions, makes it possible to explore the dose-response effects of large-scale interventions in natural experiments (Benton et al., 2016; Hunter et al., 2015).

1.4. Research gap

Although studies in the literature offer useful insights into the physical activity impact of greenspace interventions, three major research gaps may prevent the use of their findings for evidence-based policy development related to greenspace interventions.

First, the dose-response effects of greenspace interventions remain unclear, especially for large-scale greenspace interventions. This may be due to the paucity of large-scale greenspace interventions to date. Previous natural experimental studies often used a single distance threshold to allocate participants to the groups exposed and unexposed to small- or medium-scale greenspaces. However, the distance threshold often varied across studies. Such inconsistent threshold selection may partly explain the inconsistent findings of these studies (J. S. Benton et al., 2016; Hunter et al., 2015). Large-scale greenspace interventions may have stronger physical activity effects on the people who live closer to the interventions. These effects may gradually diminish with distance to the intervention because accessibility affects greenspace usage and overall physical activity (Coutts, 2008; Dallat et al., 2014; Liu et al., 2016). The dose-response effect, also called the distance decay law, has been well established in the fields of transportation and geography (Gao et al., 2013; Krizek et al., 2007; Prins et al., 2014). However, it has not yet been tested in the context of large-scale greenspace interventions.

Second, most natural experimental studies reported thus far have not controlled for neighbourhood characteristics, such as socioeconomic status (SES) and built environmental features. In natural greenspace intervention experiments, participants have not been randomly assigned to the exposed or unexposed group. Participants from different neighbourhoods may differ in various aspects at the neighbourhood level. The findings of cross-sectional studies suggest that the effects of greenspaces on physical activity may be stratified by various neighbourhood characteristics (Bancroft et al., 2015; Coutts, 2008; Jones et al., 2009; McCormack et al., 2008). For example, high-income neighbourhoods may have more and better parks than low-income neighbourhoods (Li et al., 2019). Hence, the creation of a new greenspace intervention may have a stronger effect on residents belonging to low-income neighbourhoods, who had low accessibility to parks before. As such, to rule out any potential bias related to non-random assignment, it is important to conduct sensitivity analyses by controlling for neighbourhood covariates.

Third, most natural experimental studies on greenspace interventions have been conducted in low-density cities in developed countries, such as the US and Australia (Astell-Burt et al., 2016; Bohn-Goldbaum et al., 2013; Clark et al., 2014; Cohen et al., 2013; Stephanie T. West and Shores, 2015), and only two studies have been conducted in medium-density cities in the UK (Jack S. Benton et al., 2018; J. S. Benton et al., 2016). The effects of greenspace interventions in developing countries such as China have largely been under-investigated, despite substantial investments in urban greenspaces in China. For example, China spent US$26 billion on urban greenspace infrastructure in 2018 alone (Ministry of Housing and Urban-Rural Development of China, 2020). In addition, there are notable cultural and built environmental differences across countries. Compared with the residents of developed countries, those of developing countries are physically more active due to the lower level of motorisation and the higher prevalence of jobs that require MVPA (Dumith et al., 2011; Hallal et al., 2012). The lowest rates of physical inactivity were observed in developing countries in a global study involving 1.9 million participants (Guthold et al., 2018). It is unclear how greenspace interventions can increase physical activity levels among the residents of developing countries, who are generally physically active. Research in developing countries may help establish the generalisability of the physical activity benefits of greenspace interventions. Furthermore, greenspace interventions in developing countries, such as China, are often larger than those in developed countries. For example, compared to the 2-km-long neighbourhood greenway and the 27-km-long city-wide greenway in Canada and Australia, respectively (Frank et al., 2019; Merom et al., 2003), the East Lake greenway in Wuhan, China, has a length of 102 km. It has emerged as a major city landmark, attracting more than 40 million local and non-local visitors between 2017 and 2019. After its construction, this project was endorsed by the Joint United Nations Humans Settlements Programme (UN-Habitat) and has since become a benchmark for greenspace interventions in other Chinese cities. Therefore, the East Lake greenway project offers a good opportunity to explore the impact of large greenspace interventions. Specifically, this greenway was developed from a major traffic artery in the city centre by the local government between 2016 and 2017. The 28-km-long first phase of the greenway was completed in December 2016, and the 74-km-long second phase was completed in December 2017. Pre-intervention and follow-up assessments of physical activity were conducted in April 2016 and April 2019, respectively.

1.5. Our study

We adopt a prospective natural experimental approach to explore the impact of physical activity of a large-scale greenspace intervention in Wuhan, China, which was constructed in 2016–2017. Two waves of physical activity data were collected from 1020 participants residing at different distances from the greenway in 2016 and 2019, that is, before and after the greenway interventions, respectively.

This study contributes to methodological and knowledge development in three ways. First, we compare the benefits of physical activity for people living within 1–5 km of the greenway. Hence, we explore the dose-response effect of this large-scale intervention. Second, we extend previous natural experimental methods by considering how neighbourhood-level built environment characteristics affect physical activity. Third, this is the first study to explore the impact of a greenspace intervention in a developing country. All previous natural experimental studies were conducted in developed countries. It is important to extend the evidence on the impact on physical activity of greenspace interventions to other geographical locations, such as China, a populous country with distinctive social (e.g. relatively active lifestyles) and urban (e.g. high urban density) contexts. Possible converging evidence from multiple countries can establish the generalisability of the physical activity benefits of greenspace interventions to help decision makers develop evidence-based policies in the long term.

2. Methods

2.1. Study area and sampling methods

Study area. This study focused on the East Lake greenway in Wuhan, a city in central China (Fig. 1). Wuhan has a population of 11.1 million and a total area of 8494.4 km^2. Wuhan, known as the "city of hundreds of lakes", is dotted with nearly 200 lakes, and the East Lake (*Donghu* in Chinese) is the largest urban lake in China.

The East Lake greenway project represents a classic case of a greenspace intervention to improve urban environmental and public health. The greenway is considered both a natural corridor and a traffic-free pathway located in the city centre, providing opportunities for recreation, physical activity, and active travel. It winds through the East Lake and connects five scenic spots that include parks, rivers, forests, and historic sites. The construction of the first and second phases of the greenway was completed in 2017. The original vehicle roads were converted into a 102-km-long greenway—a mix of biking lanes and walking trails, with adequate service facilities and pleasant landscapes.

Survey. A baseline survey of physical activity was conducted before the greenway intervention in April 2016, and a follow-up survey was conducted after implementation of the greenway intervention in April 2019, thus providing the respondents with approximately two and a half years of exposure to the greenway before the post-intervention survey. The baseline and follow-up surveys included identical questions concerning the respondents' physical activity levels in the previous seven days. In addition, data on the respondents' individual factors were collected in the baseline survey.

Data on daily temperature, humidity, precipitation, and number of rainy days for the periods corresponding to the baseline and follow-up surveys were obtained from China Meteorological Administration. The records indicated that the weather conditions were essentially the same during both surveys (Table 1).

Sampling and participants. A multistage stratified sampling process was used to select the study neighbourhoods and participants. First, we created five street-network buffers with 1–5 km from three main entrances to the East Lake greenway: Liyuan entrance, Yikeshu entrance, and Forest Park entrance (Fig. 1).

The 5-km distance threshold was adopted in this study for two reasons. 1) Several studies have used this distance threshold to measure the exposure to large-scale greenspace or greenway projects (Astell-Burt et al., 2016; Merom et al., 2003). 2) Urban neighbourhood-, district-, and city-level greenways (such as East Lake greenway) in China are planned to have service distances of 0.5 km, 1 km, and 4–5 km, respectively (K. Liu et al., 2016). Therefore, the 5-km radius was used in this study. Furthermore, the street-network buffers were created from the 2016 street centreline data, which were obtained from the Wuhan Land Resources and Planning Information Centre. The street centreline data were comprehensive and accurate for our study area. These street-network buffers were created only on the land side of the greenway entrances, excluding the water side, where there are no residential buildings (Fig. 1).

Second, a total of 52 neighbourhoods (*Xiaoqu* in Chinese) were selected, with roughly equal numbers of high-SES and low-SES neighbourhoods in each street-network buffer. We used the average housing prices within these neighbourhoods as a proxy for the SES of the residents (Moudon et al., 2011) because 77.7% of Chinese household wealth is invested in real estate (Economics, 2019). The 2016 median housing

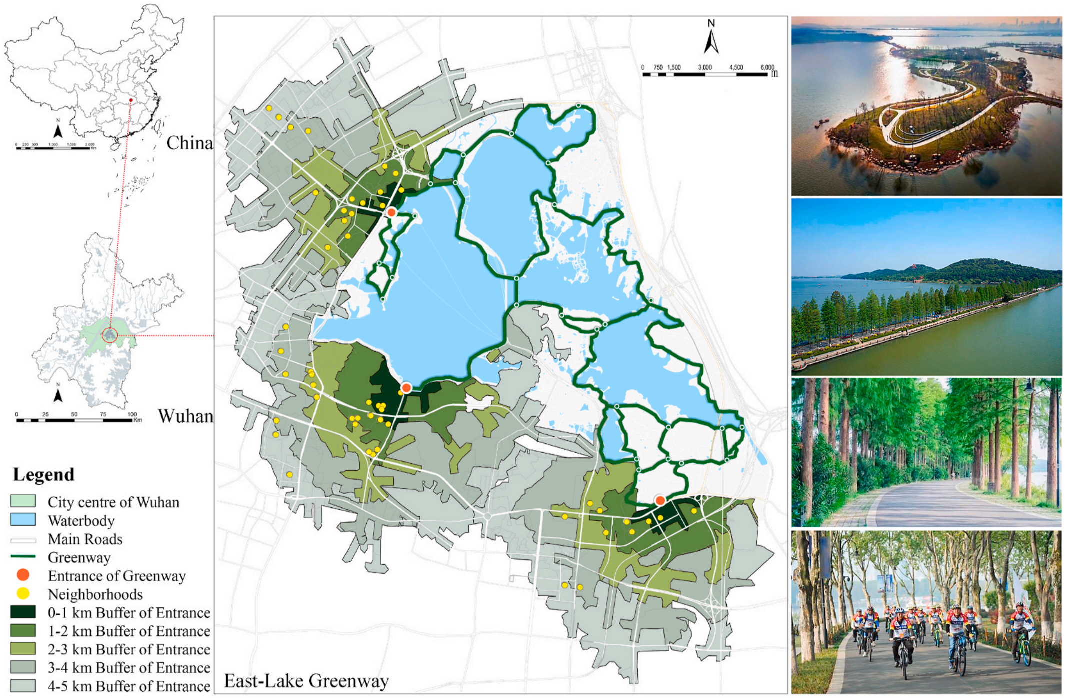

Fig. 1. Locations of Wuhan and East Lake greenway (left). A total of 1020 participants from 52 neighbourhoods within a 1–5 km street-network buffer around the three main entrances of the greenway were interviewed in this study (middle). The 102-km-long East Lake greenway is one of largest urban greenways in China (right).

Table 1
Weather conditions in the baseline and follow-up survey periods.

Year	Month	Daily temperature (°C)	Daily humidity (%)	Daily precipitation (mm)	Number of rainy days
		Mean (SD)	Mean (SD)	Mean (SD)	days
2016 (baseline)	April	21.97 (3.36)	69.87 (11.63)	20.78 (24.45)	16
2019 (follow-up)	April	21.75 (4.51)	60.00 (10.43)	29.91 (21.94)	14

prices of the urban centre of Wuhan was used as a cut-off value to determine neighbourhood SES. Neighbourhoods with average housing prices ≥20,000 CNY/m^2 and <20,000 CNY/m^2 were considered high- and low-SES neighbourhoods, respectively.

Third, face-to-face interviews were conducted by trained research assistants in the sampled neighbourhoods. The number of participants interviewed in each neighbourhood was proportional to the total number of residents in that neighbourhood. The participants in the neighbourhoods located within the 1-km and 2-km buffers were oversampled because they were more likely to be affected by this greenway intervention. Moreover, high-SES neighbourhoods were oversampled with the 1-km buffer because most neighbourhoods within a 1-km buffer were high-SES given their prime location by the East Lake (Jang and Kang, 2015; Vias and Carruthers, 2005).

Specifically, 11 two-person teams conducted both surveys. Each neighbourhood was visited by one team over a weekend. Informed consent was obtained from each participant. A gift amounting to approximately 100 CNY was given to each participant during the baseline survey, and a gift worth approximately 200 CNY was given to each participant during the follow-up survey.

In the baseline survey, more than 4000 residents were approached, and 2331 valid responses were obtained. The response rate was appropriately 50%. In the follow-up survey, participants were excluded if they did not participate in the second wave. The final sample size was 1020 participants. The retention rate was 43.8%.

Defining exposure to greenway. Exposure to the greenway was defined in two ways: a categorical measure (exposed vs unexposed groups) and a continuous measure based on distance to the greenway (0–1, 1–2, 2–3, 3–4, and 4–5 km).

In terms of the categorical measurement, the eligible participants were divided into the exposed and unexposed groups with a threshold distance of 2 km. Although the appropriate threshold was yet to be determined for this large-scale greenway, a few studies from the literature provided relevant insights. For example, a natural experimental study defined neighbourhoods located within 1.5 km from a trail as the experimental group and neighbourhoods located within 1.5–5 km as the control group (Merom et al., 2003). A case study in Wuhan reported that people may frequently visit large-scale parks within a range of 1.8 km from their residence (Xie et al., 2018). Hence, participants living in the neighbourhoods within the 2-km network buffer from the main entrances of the greenway were included in the exposed group (i.e. 0–1 km and 1–2 km buffers in Fig. 1) and those living within 2–5 km were included in the unexposed group (i.e. 2–3 km, 3–4 km, and 4–5 km buffers Fig. 1).

In terms of continuous measurement, residents' exposure to the greenway was measured by the graded distance to the greenway for practical reasons. Those living in the 0–1 km buffer were assigned a graded distance of 1 km; those living in the 1–2 km buffer were assigned a graded distance of 2 km; and so on. As noted by some researchers, the dichotomy of exposed and unexposed groups with inconsistent distance thresholds may lead to inconsistent results (Frank et al., 2019; S. T. West and Shores, 2011). A continuous measurement might accurately assess the fine-grained exposure level to the greenway.

2.2. Data measurements

Physical activity measurements. The International Physical Activity Questionnaire (IPAQ-SF12) is considered a reliable and valid instrument for assessing physical activity (C. L. Craig et al., 2003). In the current study, MVPA was assessed by asking the following questions: "During the last seven days, on how many days did you do moderate/vigorous physical activities at least 10 min at a time?" and "How much time in total did you usually spend on one of those days doing moderate/vigorous physical activities?" The total MVPA duration in minutes per week was calculated as one physical activity outcome. The overall physical activity energy expenditure was calculated as MET minutes per week, as suggested in the IPAQ protocol. MET minutes represent the amount of energy expended when engaging in such physical activity.

Personal factors. The participants were asked about their age, gender, marital status, employment status, educational attainment, and annual household income in the baseline survey (April 2016).

Neighbourhood environment. All built environmental variables of the sampled neighbourhoods were measured in the baseline period using ArcGIS 10.5. A 500-m street-network buffer was created from the centroid of each sampled neighbourhood. Within this buffer, the population density, building density, floor area ratio, land-use mix, street connectivity (street intersection density), number of parks, and number of bus stops were calculated. To rule out potential multicollinearity, the population density and floor area ratio were excluded from the analysis because their variance inflation factor was ≥4.

2.3. Statistical analyses

The participants' physical activity behaviours, individual factors, and neighbourhood characteristics in different buffers (1–5 km) were reported in terms of means and standard deviations (SDs) for the continuous variables and in terms of percentages for the categorical variables. The participants' physical activity during the baseline and follow-up periods were compared using paired t-tests.

Mixed-effects difference-in-difference regressions were conducted to examine the effects of greenway exposure on changes in physical activity, with a random interception for subjects and neighbourhoods. The multilevel models accounted for participant clustering at the neighbourhood level.

A two-step analysis with three models in each step was implemented. In the first step, greenway exposure was measured as a binary variable (exposed vs. unexposed), as done in previous greenspace natural experimental studies (Clark et al., 2014; Frank et al., 2019). Model 1 was a basic difference-in-difference model.

$$Physical\ Activity_{ij} = \beta_0 + \beta_1\ Exposure_{ij} + \beta_2\ Time_{ij} + \beta_3\ Exposure_{ij} * Time_{ij} + (\varepsilon_{ij} + \mu_j) \quad (1)$$

where *Physical Activity*$_{ij}$ is the MVPA or overall physical activity levels of participant i in neighbourhood$_j$; β_1 captures the net difference between participants with or without greenway exposure (exposed vs. unexposed); β_2 captures the net physical activity difference between participants in the follow-up and baseline periods; *Exposure* × *Time* is an interaction term representing the difference-in-differences estimate of the impact of the greenway intervention; ε_{ij} is the individual-level error term; and μ_j is the neighbourhood-level error term. In Model (1), if β_3 is statistically significant, it can be concluded that the greenway intervention has increased the physical activity levels of the participants.

Because the treatment condition was not randomly assigned by the researchers, the participants in the exposed and unexposed groups may have differed in terms of personal factors as well as neighbourhood environment. Therefore, to account for possible biases, individual and neighbourhood covariates were further added into the difference-in-difference Models (2) and (3).

$$Physical\ Activity_{ij} = \beta_0 + \beta_1\ Exposure_{ij} + \beta_2\ Time_{ij} + \beta_3\ Exposure_{ij} * Time_{ij} + \beta_4\ Individual_{ij} + (\varepsilon_{ij} + \mu_j) \quad (2)$$

where *Individual*$_{ij}$ is a vector of individual covariates.

$$Physical\ Activity_{ij} = \beta_0 + \beta_1\ Exposure_{ij} + \beta_2\ Time_{ij} + \beta_3\ Exposure_{ij} * Time_{ij} + \beta_4\ Individual_{ij} + \beta_5\ Neighbourhood_j + (\varepsilon_{ij} + \mu_j) \quad (3)$$

where *Neighbourhood*$_j$ is a vector of neighbourhood covariates.

If β_3 remains statistically significant after introducing the covariates, it is feasible that the non-random assignment does not affect the original estimate.

In the second step, greenway exposure was measured as a continuous variable (1 km, 2 km, 3 km, 4 km, and 5 km) to explore the dose-response effect. Similar to the procedure in the first step of the analysis, Model 4 was created as a basic difference-in-difference model. Model 5 was created with additional individual covariates, and Model 6 was created with additional neighbourhood covariates. The β_3 values yielded by these three models indicated how the effects of greenway exposure varied with one SD change in distance to the greenway. All of the analyses were conducted using R (version 3.6) (R Core Team, 2014), and the lme4 package was used to fit the multilevel models (Bates et al., 2015).

3. Results

3.1. Descriptive statistics

Table 2 compares the demographic characteristics of the sampled participants with those of the overall population in urban centre of Wuhan, which contains our study area. The census data for our study area were unavailable, so we used the census data of the entire urban centre as proxy. The age, gender, employment, and household income data of the residents of the urban centre were retrieved from the Wuhan

Table 2
Demographic characteristics of the sampled participants and those of the population in the urban centre.

	Age (Mean)	Gender (% female)	Employment (% employed)	Household income (000CNY/year)
Sampled participants	50.8	56.6%	55.9%	202.3
Study area	48.6	51.5%	51.1%	143.8

Table 3
Descriptive characteristics of the participants, physical activity, and neighbourhood environment (n = 1020).

Variables	0–1 km	1–2 km	2–3 km	3–4 km	4–5 km	Exposed group	Unexposed group	Overall
	Mean (SD)/%	Mean (SD)/%	Mean (SD)/%	Mean (SD)/%	Mean (SD)/%	Mean (SD)/%	Mean (SD)/%	Mean (SD)/%
Physical activity								
MVPA at baseline (min/week)	612.8 (631.9)	714.2 (727.4)	625.4 (592.9)	609.8 (524.9)	801.3 (670.1)	657.2 (676.8)	668.5 (596.9)	660.0 (657.5)
MVPA at follow-up (min/week)	697.0 (683.8)	749.3 (733.5)	646.8 (620.9)	611.3 (521.5)	793.3 (665.6)	719.9 (706.0)	675.0 (604.3)	708.7 (682.0)
Changes in MVPA (min/week)	84.2 (385.5)***	35.0 (197.3)**	21.4 (227.3)	1.5 (97.9)	-8.0 (76.6)	62.7 (318.0)***	6.5 (156.9)	48.7 (287.4)
Overall PA at baseline (MET-min/week)	4072.8 (3289.0)	4602.7 (4112.2)	4405.5 (3136.2)	4365.5 (3538.0)	4807.4 (3670.8)	4304.5 (3678.6)	4502.5 (3420.2)	4353.8 (3615.4)
Overall PA at follow-up (MET-min/week)	4626.2 (3438.4)	4917.1 (4249.0)	4435.1 (3232.8)	4385.4 (3575.7)	4668.1 (3670.7)	4753.4 (3814.3)	4482.3 (3464.1)	4685.9 (3730.3)
Changes in overall PA (MET-min/week)	553.5 (1925.4)***	314.4 (1440.0)***	29.6 (1263.4)	19.9 (614.8)	-139.3 (537.3)	448.9 (1733.0)***	-20.3 (904.6)	332.1 (1580.8)
Individual factors								
Age	49.4 (16.4)	51.1 (16.2)	51.6 (15.4)	52.3 (14.3)	54.9 (16.8)	50.1 (16.3)	52.8 (15.4)	50.8 (16.1)
Gender (% female)	60.1%	49.9%	57.7%	62.1%	58.6%	55.6%	59.2%	56.6%
Education (% ≥ college)	46.6%	53.1%	60.8%	48.3%	47.1%	49.5%	52.5%	50.3%
Employment (% employed)	54.1%	64.5%	48.5%	41.4%	54.3%	58.6%	47.5%	55.9%
Marital status (% married)	85.4%	82.4%	81.4%	80.5%	84.3%	84.1%	81.6%	83.5%
Household income ('000 CNY/year)	218.4 (200.9)	185.0 (204.3)	280.8 (599.8)	134.7 (85.9)	161.2 (198.4)	203.8 (202.9)	197.8 (392.6)	202.3 (263.1)
Neighbourhood characteristics								
Building density	0.18 (0.06)	0.19 (0.05)	0.21 (0.07)	0.25 (0.12)	0.20 (0.04)	0.18 (0.05)	0.22 (0.09)	0.19 (0.06)
Land-use mix	1.64 (0.45)	1.76 (0.45)	1.85 (0.25)	1.38 (0.38)	1.57 (0.31)	1.69 (0.45)	1.61 (0.37)	1.67 (0.43)
Street intersection density	7.40 (2.31)	5.71 (0.97)	6.02 (1.20)	5.63 (0.86)	7.26 (0.43)	6.66 (2.03)	6.23 (1.13)	6.55 (1.86)
Number of parks	0.23 (0.42)	0.76 (1.10)	0.03 (0.31)	0.05 (0.30)	0.00 (0.00)	0.46 (0.83)	0.03 (0.26)	0.36 (0.76)
Number of bus stops	3.25 (2.62)	2.63 (1.84)	2.00 (1.06)	1.63 (1.34)	1.34 (1.26)	2.98 (2.33)	1.69 (1.24)	2.66 (2.18)
Neighbourhood SES (% high)	76.1%	45.1%	52.6%	46.0%	45.7%	62.5%	48.4%	59.0%
Number of participants	431	335	97	87	70	766	254	1020

Note: The participants' individual factors and the neighbourhood characteristics were collected in the baseline survey. Paired t-tests were conducted to compare the participants' physical activity levels during the baseline and follow-up periods, and the results are labelled with asterisks in the rows showing physical activity changes (changes = PA at follow-up – PA at baseline).
*$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$.

Table 4
Regression estimates of the physical activity benefits of greenway exposure measured as a binary variable (exposed vs. unexposed groups) (total n = 1020).

	MVPA			Overall physical activity		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Model predictors	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)
Greenway exposure	0.053 (−0.149, 0.260)	0.050 (−0.145, 0.249)	−0.007 (−0.210, 0.182)	−0.005 (−0.187, 0.182)	−0.019 (−0.192, 0.159)	−0.061 (−0.232, 0.083)
Time	0.010 (−0.043, 0.062)	0.010 (−0.043, 0.062)	0.010 (−0.043, 0.062)	−0.006 (−0.058, 0.047)	−0.006 (−0.058, 0.047)	−0.006 (−0.058, 0.047)
Greenway exposure × time	0.084 (0.023, 0.145)**	0.084 (0.023, 0.145)**	0.084 (0.023, 0.145)**	0.128 (0.067, 0.188)***	0.128 (0.067, 0.188)***	0.128 (0.067, 0.188)***
Individual factors						
Age		0.120 (0.060, 0.181)***	0.104 (0.044, 0.164)***		0.099 (0.039, 0.160)***	0.086 (0.024, 0.144)**
Gender (female vs. male)		0.057 (−0.064, 0.178)	0.065 (−0.057, 0.181)		0.033 (−0.091, 0.153)	0.038 (−0.088, 0.153)
Education (≥college vs. others)		−0.132 (−0.263, −0.005)*	−0.089 (−0.225, 0.032)*		−0.201 (−0.331, −0.073)**	−0.169 (−0.304, −0.049)**
Employment (employed vs. not)		0.112 (−0.018, 0.243)	0.089 (−0.038, 0.219)		0.130 (0.000, 0.262)	0.111 (−0.021, 0.239)
Marital status (married vs. others)		0.033 (−0.130, 0.193)	0.037 (−0.126, 0.191)		0.009 (−0.156, 0.169)	0.013 (−0.158, 0.162)
Household income		−0.023 (−0.085, 0.037)	−0.009 (−0.071, 0.051)		−0.042 (−0.104, 0.018)	−0.031 (−0.093, 0.029)
Neighbourhood characteristics						
Building density			−0.147 (−0.229, −0.064)***			−0.116 (−0.191, −0.036)**
Land-use mix			−0.036 (−0.133, 0.062)			−0.019 (−0.099, 0.049)
Street intersection density			0.019 (−0.065, 0.103)			−0.002 (−0.075, 0.068)
Number of parks			0.211 (0.081, 0.343)**			0.175 (0.052, 0.274)*
Number of bus stops			−0.151 (−0.235, −0.051)**			−0.109 (−0.169, −0.019)*
Neighbourhood SES (high vs. low)			−0.223 (−0.392, −0.070)*			−0.168 (−0.321, −0.049)*

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$.

Statistical Yearbook (Statistics, 2017). The demographic characteristics of the sampled participants were similar to those of the overall population of the urban centre, except for household income. The sampled participants had higher household incomes than the overall population. The spatial mismatch between our study area and the urban centre may have caused this difference because although the urban centre contains the study area, it is considerably larger than the study area.

Table 3 shows the descriptive statistics of physical activity, individual characteristics, and neighbourhood environment of the study participants. At the baseline level, the MVPA of the participants in the exposed group did not differ significantly from that in the unexposed group (657.2 vs. 668.5 min/week). Similarly, the overall physical activity level in the exposed group did not significantly differ from that in the unexposed group (4304.5 vs. 4502.5 MET-min/week). In the follow-up period, the MVPA and overall physical activity of the exposed group significantly increased by 62.7 min/week and 448.9 MET-min/week in absolute terms and by 9.5% and 10.4% in percentage terms, respectively, compared with the baseline level.

In terms of the individual characteristics, the average ages of the participants in the exposed and control groups were 50.1 and 52.8 years, respectively. There were more female participants than male (56.6% vs 43.4%), and the female ratio was lower in the exposed group than that in the unexposed group (55.6% vs 59.2%). Most of the participants were married (83.5%), and the ratio in the exposed group was slightly higher than that in the unexposed group (84.1% vs 81.6%). More than 50% of the participants were educated to the college level or higher, but the ratio in the exposed group was slightly lower than that in the unexposed group (49.5% vs. 52.5%). More than half (55.9%) of the participants were employed, and the employment ratio was higher in the exposed group than that in the unexposed group (58.6% vs 47.5%). Moreover, the household incomes of the participants in the exposed group were higher than those of their counterparts in the unexposed group.

In terms of the neighbourhood environment, comparisons of the exposed and unexposed groups yielded no significant differences for most variables, including building density, land-use mix, street intersection density, and number of bus stops, reflecting a high similarity in neighbourhood environments between the two groups. However, the sampled neighbourhoods in the exposed group tended to have more parks that those in the unexposed group (0.46 vs. 0.03).

3.2. Intervention effect of the large-scale urban greenway on physical activity

In the first analysis step, greenway exposure was measured as a binary variable. Table 4 presents the results obtained by fitting three models (1, 2, and 3). The estimated interaction terms in Model 1 revealed that when unadjusted for covariates, the effects of the greenway interaction on both MVPA and overall physical activity were significant. More importantly, the coefficients remained unaffected and significant after adjusting for individual and neighbourhood covariates (Models 2 and 3). The effect sizes on MVPA and the overall physical activity levels were relatively small (0.084 SD) and large (0.128 SD), respectively.

Notably, age was positively related to both MVPA and overall physical activity. Educational attainment was negatively related to MVPA and overall physical activity, and participants with a college degree or higher had lower levels of MVPA and overall physical activity compared with others. In terms of neighbourhood covariates, building density, number of bus stops, and neighbourhood SES (high vs low) were negatively related to MVPA and overall physical activity. The number of

Table 5
Regression estimates of the physical activity benefits of greenway exposure measured as a continuous variable (1–5 km) (total n = 1020).

	MVPA			Overall physical activity		
	Model 4	Model 5	Model 6	Model 4	Model 5	Model 6
Model predictors	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)
Greenway exposure	0.048 (−0.048, 0.144)	0.045 (−0.049, 0.138)	0.060 (−0.026, 0.155)	0.086 (−0.002, 0.173)	0.085 (0.001, 0.170) *	0.090 (0.018, 0.171)
Time (post vs. pre)	0.073 (0.046, 0.099)***	0.073 (0.046, 0.099) ***	0.073 (0.046, 0.099) ***	0.090 (0.064, 0.116) ***	0.090 (0.064, 0.116) ***	0.090 (0.064, 0.116) ***
Greenway exposure × time	−0.046 (−0.072,- 0.020)***	−0.046 (−0.072, −0.020)***	−0.046 (−0.072, −0.020)***	−0.061 (−0.087, −0.035)***	−0.061 (−0.087, −0.035)***	−0.061 (−0.087, −0.035)***
Individual factors						
Age		0.120 (0.060, 0.181) ***	0.104 (0.044, 0.164) ***		0.099 (0.039, 0.160) ***	0.086 (0.024, 0.145) **
Gender (female vs. male)		0.056 (−0.065, 0.176)	0.065 (−0.058, 0.181)		0.032 (−0.092, 0.152)	0.038 (−0.088, 0.153)
Education (≥college vs. others)		−0.134 (−0.264, −0.006)*	−0.090 (−0.226, 0.031)		−0.202 (−0.332, −0.075)**	−0.169 (−0.303, −0.049)**
Employment (employed vs. not)		0.115 (−0.014, 0.246)	0.090 (−0.036, 0.220)		0.133 (0.003, 0.264) *	0.111 (−0.021, 0.238)
Marital status (married vs. others)		0.033 (−0.129, 0.193)	0.037 (−0.126, 0.191)		0.009 (−0.156, 0.169)	0.013 (−0.158, 0.162)
Household income		−0.024 (−0.085, 0.037)	−0.010 (−0.071, 0.051)		−0.042 (−0.104, 0.018)	−0.031 (−0.093, 0.029)
Neighbourhood characteristics						
Building density			−0.148 (−0.231, −0.066)***			−0.116 (−0.190, −0.036)**
Land-use mix			−0.034 (−0.132, 0.062)			−0.019 (−0.099, 0.049)
Street intersection density			0.018 (−0.066, 0.103)			−0.003 (−0.075, 0.068)
Number of parks			0.215 (0.088, 0.343) **			0.175 (0.054, 0.269) **
Number of bus stops			−0.150 (−0.233, −0.050)**			−0.109 (−0.169, −0.019)*
Neighbourhood SES (high vs. low)			−0.224 (−0.393, −0.069)*			−0.169 (−0.321, −0.048)*

Note: *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$.

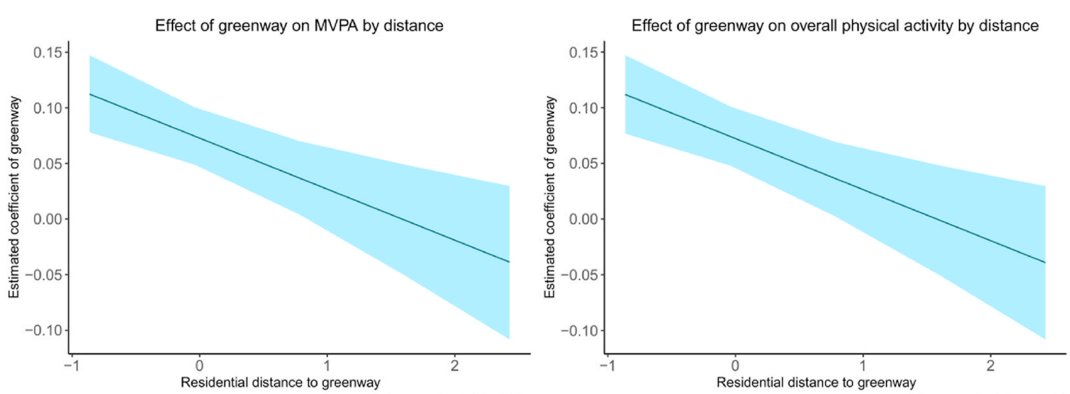

Fig. 2. Dose-response effects of greenway intervention on changes in MVPA (left) and overall physical activity (right) by distance in Model 6. The effects of greenway interventions on both MVPA and overall physical activity decreased with distance. The individual and neighbourhood covariates were controlled for in this model. Note: Both distance and physical activity values were standardised z scores.

parks was positively related to MVPA and overall physical activity.

In the second analysis step, greenway exposure was measured as a continuous variable. Table 5 presents the results obtained by fitting three models (4, 5, and 6). In Model 4, the interaction term was significant for both MVPA and overall physical activity. The coefficient of the interaction term of Model 4 indicated that the effect of the greenway intervention on MVPA decreased by −0.046 SD as the distance increased by one SD. The same result held for overall physical activity. The effect of the greenway intervention decreased with distance, with an effect size of −0.061. Most importantly, the effect sizes of both interaction terms remained unchanged after the addition of the individual and neighbourhood covariates (Models 5 and 6), indicating that the non-random assignment of the participants did not affect the physical activity benefits of the greenway intervention. Fig. 2 shows a plot of the dose-response effect of the greenway intervention on both outcomes as a function of distance in Model 6. The linear and decreasing dose-response effect of the greenway intervention by distance is evident from this plot.

Age was positively related to both MVPA and overall physical activity, and educational attainment (those with college degrees or higher vs. others) was negatively related to MVPA and overall physical activity, except in Model 6. In terms of the neighbourhood covariates, building density, number of bus stops, and neighbourhood SES (high vs. low) were negatively related to MVPA and overall physical activity. The number of parks was positively related to MVPA and overall physical activity.

4. Discussion

In this study, we investigated the physical activity benefits of a large-scale urban greenway intervention by adopting a natural experimental approach. The results agree with those of previous natural experimental studies that reported the positive impact of small- and medium-scale urban greenspace interventions on physical activity, including parks (Cohen et al., 2009; Fitzhugh et al., 2010; Veitch et al., 2012), greenways (Fitzhugh et al., 2010; Frank et al., 2019), and greening of vacant urban lots (Branas et al., 2011). Moreover, the results of this study supplement those of cross-sectional studies (Bancroft et al., 2015; Liu et al., 2019a; b; Lu et al., 2018a; Zuniga-Teran et al., 2019) by providing more rigorous evidence of the contribution of large-scale greenspace interventions to increased MVPA and overall physical activity.

This study contributes to the existing knowledge in four ways.

First, the present study is one of the first to report the dose-response effects of a large-scale greenspace intervention given the vast scale of the studied urban greenway intervention. The potentially large geographical reach of physical activity benefits associated with the East Lake greenway project enabled us to use graded greenway exposure to explore the dose-response effects.

Most natural experimental studies in the literature have treated greenspace exposure as a binary variable (exposed vs. unexposed) by using a single distance threshold. However, this dichotomy of greenspace exposure with a given distance threshold may lead to inconsistent findings (J. S. Benton et al., 2016; Hunter et al., 2015). For example, Frank et al. (2019) reported 500 m as the threshold for participants to receive physical activity benefits from a 2-km-long greenway. In another study, increased walking was reported in residents living within 1.5 km of a 16.5-km-long trail (Merom et al., 2003). In contrast, Evenson et al. (2005) did not find any physical activity benefits for residents living within 3.2 km of a 10-km-long trail. The selection of an optimised threshold may be affected by various factors, such as the scale and type of greenspace interventions, specific domain of physical activity of interest, and cultural or social contexts. In this study, we provided an alternative method to measure graded greenway exposure that can be applied to natural experimental studies of large-scale greenspace interventions in the future.

Second, we found that the effects of the greenway intervention weakened with increasing distance. Specifically, the physical activity benefits were the greatest for the residents living within 2 km of the greenway, and they gradually declined as the residential distance increased to 5 km from the greenway. This specific dose-response effect may be supported by the proposition that the distance to an urban greenspace plays a crucial role in promoting physical activity (Coutts, 2008). A multi-country cross-sectional study observed that the MVPA of the participants living within 1 km of a greenspace was higher (Schipperijn et al., 2017). Another study found that residing within 500 m from a park could increase park use and total physical activity (Liu et al., 2017). From the planning perspective, many Chinese cities have implemented the concept of *15-min life circles* in recent years, which suggests that residents should be able access an urban greenspace within 15-min walking distance, or roughly 1.2 km (Fu and Shen, 2019).

However, the effective distance for the considered greenway intervention was found to be up to 2 km, which is longer than the distance thresholds reported in previous studies (Evenson et al., 2005; Merom et al., 2003; Stephanie T. West and Shores, 2015). The longer effective distance may be explained by the vast size and excellent quality of this greenway intervention. The 102-km-long East Lake greenway is considerably longer than any of the greenways reported in previous natural experimental studies (Fitzhugh et al., 2010; Frank et al., 2019). In comparison, the Comox greenway project in Canada is 2 km long (Frank et al., 2019), and the Knoxville-Knox County greenway in the US is 4.6 km long (Fitzhugh et al., 2010). In addition, the East Lake greenway, which is dotted by lakes, forests, and heritage sites, is of excellent quality. The quality of an urban greenspace strongly affects nearby residents' physical activity and health (de Vries et al., 2016; White et al., 2016). Therefore, residents within a distance of 2 km from the East Lake greenway intervention may accrue physical activity benefits from it.

Third, we conducted a sensitivity analysis by adding neighbourhood-level covariates that were not controlled for in previous natural experimental studies. Unlike fully controlled experiments, such as RCTs, in natural experimental studies the participants are not randomly assigned to the groups exposed and unexposed to greenspace interventions. Such non-random assignment introduces potential bias due to unbalanced covariates between the exposed and unexposed groups (Craig et al., 2017). For example, the neighbourhoods closer to urban greenspaces tend to have higher SES (Heckert, 2013; Kimpton, 2017). Our results demonstrated that such non-random assignment did not introduce a major bias in this study because the coefficients of the interaction terms ($exposure \times time$) remained unaffected after including both individual and neighbourhood covariates.

In this study, four neighbourhood characteristics were related to physical activity outcomes. Those living in neighbourhoods with more parks in the surroundings had higher levels of physical activity, which is consistent with the findings of previous studies (Bancroft et al., 2015; Norman et al., 2006; Scott et al., 2007; Xiao et al., 2019). Furthermore, people living in high-SES neighbourhoods had lower levels of physical activity than those in low-SES neighbourhoods. This finding is consistent with the findings of previous studies conducted in China (M. Chen et al., 2015; Shi et al., 2006). One explanation is that high-SES urban residents in China have lower levels of active travel, for instance, walking to school or work, than low-SES residents (Shi et al., 2006). Adults from lower-SES neighbourhoods might engage in more household work, thereby increasing their overall physical activity levels (M. Chen et al., 2015). However, opposite findings were observed in developed countries (Bauman et al., 2012; Michael et al., 2010; Molina-Garcia et al., 2017; Ravensbergen et al., 2016). The different social contexts in these nations may have led to these contrasting findings.

However, building density and the number of bus stops were negatively associated with physical activity, which is inconsistent with the findings of previous studies conducted in low- and medium-density cities (Ding et al., 2011; Troped et al., 2010). Notably, these findings come from cross-sectional associations found in our analysis, rather than increases in physical activity as a result of change in urban density or the number of bus stops. Our findings are consistent with those from high-density cities (Lu et al., 2017; Salvo et al., 2014; Su et al., 2014), showing that highly dense neighbourhood environments, which are beneficial for transport-related physical activity, hinder leisure-time physical activity due to perceived overcrowding (Xie et al., 2019). Meanwhile, it is feasible that the varying urban density levels in different studies have led to inconsistent findings. There potentially exists a threshold effect between physical activity and urban density (Christiansen et al., 2016; Lu et al., 2019). Hence, physical activity may be positively associated with building density until a certain threshold but negatively associated thereafter. The same applies to the number of bus stops.

Fourth, in addition to providing methodological development and knowledge insights, the present study is one of first natural experimental studies focusing on the physical activity benefits of greenspace interventions in a high-density city in China. Although many developing countries are populous, such as China, evidence on the physical activity benefits of greenspace interventions is scarce. In addition, Chinese metropolitan areas have many distinctive built environments and social features compared with low-density Western cities, such as considerably higher urban densities and physically more active populations. The converging evidence from this study and the natural experimental studies conducted in developed countries (Fitzhugh et al., 2010; Merom et al., 2003; Tester and Baker, 2009), suggests that the physical activity benefits of greenspaces may be generalised across different societies and geographical locations.

Finally, this research endeavour has critical planning implications for cities in China. The accelerated pace of urbanisation in China over the past three decades has led to the shrinkage of urban greenspaces and physical inactivity among urban residents (Y. Liu et al., 2019; Lu et al., 2018b). Against this backdrop, China has recently implemented the ecocity and healthy city policies. Many cities in China are planning and incorporating large-scale urban greenspaces to improve physical activity and health in recent years. However, there is scarce evidence from rigorous natural experimental studies to guide such planning activities. The lack of natural experimental studies on the effects of greenspace in China may be attributed to the fact that governments and researchers have just began to shift their focus from economic development in cities to public health and the wellbeing of urban residents (Guan et al., 2016).

Our study provides some insights to inform policies and tailor greenspace interventions in China. We find that the physical activity benefits of greenway interventions are distance-sensitive. Residents living closer to a greenway intervention tend to receive more physical activity benefits those living far away, according to our dose-response effect analysis. Therefore, poor accessibility to greenspaces might hinder greenspace use and overall physical activity. Under these circumstances, urban planners could devote more efforts to optimise the location and accessibility of greenspaces. Furthermore, urban planners could develop integrated greenspace networks to increase accessibility greenspaces, rather than providing isolated parks or greenways.

4.1. Limitations

Our study had several limitations. First, the physical activity data were self-reported and could be prone to recall bias or social desirability bias. It is worthwhile to collect objective physical activity data by using portal devices, such as accelerometers and global positioning system terminals. Moreover, it is worthwhile to evaluate greenspace usage based on systematic social observations. Second, the overall physical activity data, rather than the greenway-related physical activity data, were collected in this study. Therefore, there is a potential bias, in that the changes in physical activity may not necessarily have been caused by the greenway intervention but possibly by some unobserved changes in the social or built environment. Future studies could investigate greenway usage and examine its relationship with changes in overall physical activity. Third, the intervention exposure duration was approximately two years, which was longer than the durations in other greenspace natural experiments. Future studies could therefore explore the long-term effects (for example, 5 years or 10+ years) of large-scale greenspace interventions (Hunter et al., 2015) given the heavy financial costs associated with such interventions. Fourth, our participants had higher household incomes than the overall population of the urban centre of Wuhan. This difference may limit the potential generalisability of our findings to low-income population. Fifth, the physical activities in this study were measured in terms of MVPA and overall physical activity, which were beneficial to assess the potential health benefits and overall energy expenditures. However, the selection of such outcomes may oversimplify the complex relationship between physical activity and greenspaces. It is feasible that greenspace interventions may exert different effects on different types of physical activity, such as walking, cycling, jogging, and exercise. Future studies should explore the effects of greenspaces on various types of physical activities separately.

5. Conclusion

This natural experimental study provided robust evidence on the physical activity benefits of a large-scale greenway intervention in a dense city in China. Our results demonstrated that this large-scale greenway positively impacted both MVPA and overall physical activity after controlling for individual and neighbourhood covariates. The dose-response effect analysis revealed that the physical activity benefits of greenway interventions decrease with distance. Individuals living closer to this large-scale greenway accrued greater physical activity benefits. Investments in large-scale urban greenspaces can serve as a successful intervention strategy to stimulate physical activity and reduce healthcare burdens in dense urban areas in China.

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Ethics approval and consent to participate

Ethical approval for the study was obtained prior to this study from the Research Committee of City University of Hong Kong (No. H000691). All participants provided written informed consent.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2020.102502.

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