# Exploring Association between Neighbourhood Green Space and Physical Activity of Elderly in High Density Cities
## A Case Study of Hong Kong

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*ABSTRACT: Physical activities provide an important way for elderly people to stay health. It is widely documented that the environment in which older people live plays an important role in promoting or inhibiting physical activity. In particular, green space has been recognized as an important behaviour setting for physical activity.*

*The aim of this study is to explore the association between neighbourhood green space and elderly physical activity in Hong Kong, a typical high density and aging city in the world. In this study, (1) we analyse and assess the neighbourhood green space in Hong Kong using satellite-observed normalized difference vegetation index (NDVI), (2) we study the physical walking activity of elderly people from a prospective cohort study of 4,000 older people in Hong Kong between 2001 and 2009, and (3) we obtained the neighbourhood green space for each of the 4000 elderly by calculate the area ratio of trees using a buffer with radius ranging from 100m to 2000m. The correlation between neighbourhood green space and elderly walking activities are then investigated by conducting a regression analysis.*

*In general, we find that (1) elderly living in neighbourhoods with more green space have higher levels of participation in regular physical walking activities, (2) significant correlation can be observed between neighbourhood green space with radius larger than 1200m and regular physical walking activity, indicating green space in large neighbourhoods plays a key role in encouraging elderly to walk more. These results illustrate the necessity for improving elderly health in high density and aging society via increasing neighbourhood green space in both near and far-away neighbourhoods. This provides a basis for urban planning policy to design and encourage the use of neighbourhood green space.*

*Keywords: green space planning, NDVI, physical activity, elderly, high density, Hong Kong*

## INTRODUCTION

Hong Kong is an ageing society. An estimated 22% of its residents will be 65 years old or above by the year 2030, according to the World Health Organization. Physical activities provide an important way for older people to keep healthy. It is widely documented that the environment in which older people live plays an important role in promoting or inhibiting physical activity. In particular, green space has been recognized as an important behaviour setting for physical activity (Kaczynski, Potwarka, & Saelens, 2008; Maas, Verheij, Spreeuwenberg, & Groenewegen, 2008). It plays a significant role in supporting activities of various social groups (Barbosa et al., 2007). However, the benefit of neighbourhood green space on elderly physical activity is less studies in Hong Kong, a typical high density and aging cities. This paper used quantitative method to exploring the association between green space and physical activity. It can provide scientific evidence and information for policy making and to advance intersectional collaboration in urban planning and design.

## BACKGROUND

Hong Kong is located to the southeast of the mainland of China, adjoining the province of Guangdong, and lies between Latitude 22° 8′ North and 22° 35′ North, Longitude 113° 49′ East and 114° 31′ East. Table 1 shows the study area of 18 council districts in Hong Kong, and the population density of elderly people (age≥65). The average elderly population density is 681 people per km$^2$. From the figure, we can see that Kowloon has the highest elderly density, at 6270 person/km$^2$, and followed by Hong Kong Island (1,977 person/km$^2$), and New Territories the lowest (only 304 person/km$^2$). Kowloon, a high density district, has elder population with density as high as more than 5000 people per km$^2$ (refer to Figure 1). This high elderly density poses challenges for the society to meet social, psychological, and healthcare needs for elderly people (Woo, Yau, & Yu, 2015). Table I also shows Green Space, Ratio and Area per Elderly Person by 18 District Council (DC) District in Hong Kong.

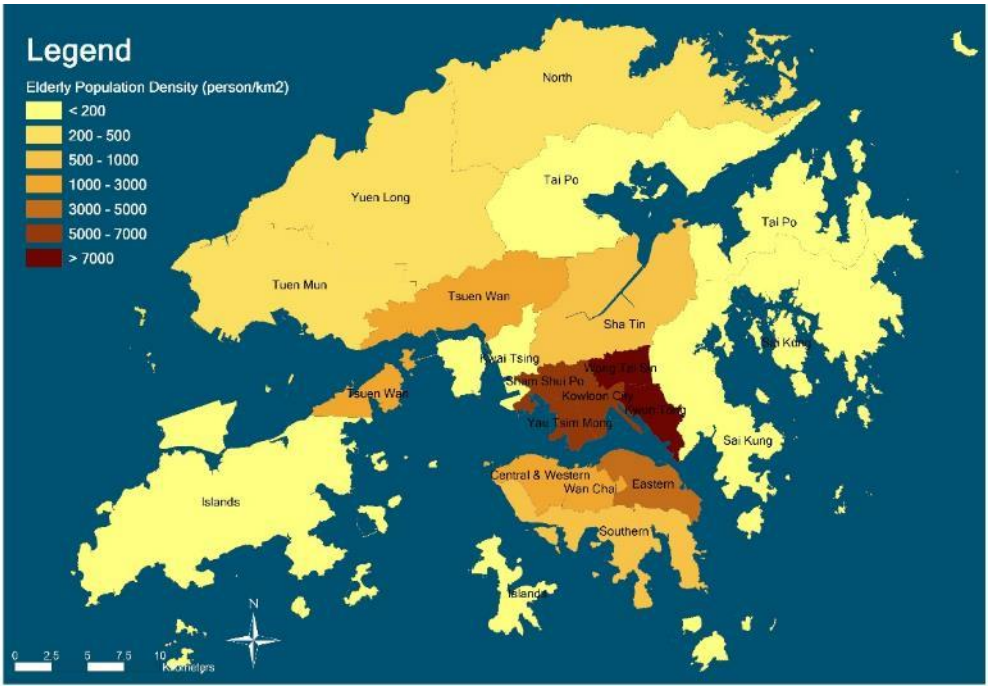


*Figure 1: The population proportion of elderly people in 18 District Council (DC) in Hong Kong.*

*Table 1: Green Space, Ratio and Area per Person by 18 District Council (DC) District in Hong Kong.*

| ID No. | Council District | Land Area ($km^2$) | 65+ Population Density (person/$km^2$) | Green Space Area ($km^2$) | Green Space Ratio (%) | Green Space per Elderly ($m^2$/person) |
|---|---|---|---|---|---|---|
| Hong Kong Island Subtotal | | 80.4 | 1 977 | 4.1 | 5.10 | 3.6 |
| HK01 | Central&Western | 12.4 | 2 309 | 0.5 | 4.18 | 2.1 |
| HK02 | Wan Chai | 9.9 | 2 170 | 0.5 | 5.05 | 3.2 |
| HK03 | Eastern | 18.7 | 4 001 | 1.0 | 5.36 | 1.7 |
| HK04 | Southern | 39.4 | 862 | 2.1 | 5.29 | 7.6 |
| Kowloon Subtotal | | 46.8 | 6 270 | 3.6 | 7.72 | 1.8 |
| KLN01 | Yau Tsim Mong | 6.9 | 5 293 | 0.7 | 9.47 | 2.3 |
| KLN02 | Sham Shui Po | 9.4 | 5 893 | 0.7 | 7.48 | 1.9 |
| KLN03 | Kowloon City | 10.0 | 5 053 | 0.8 | 7.85 | 2.2 |
| KLN04 | Wong Tai Sin | 9.3 | 7 485 | 0.7 | 7.62 | 1.7 |
| KLN05 | Kwun Tong | 11.3 | 7 202 | 0.8 | 6.83 | 1.3 |
| New Territories Subtotal | | 969.3 | 304 | 14.9 | 1.54 | 304 |
| NT01 | Kwai Tsing | 22.2 | 2 490 | 0.6 | 2.88 | 1.2 |
| NT02 | Tsuen Wan | 61.0 | 441 | 0.5 | 0.87 | 1.8 |
| NT03 | Tuen Mun | 84.3 | 398 | 0.9 | 1.07 | 1.8 |
| NT04 | Yuen Long | 138.6 | 271 | 1.6 | 1.13 | 2.9 |
| NT05 | North | 136.6 | 195 | 2.3 | 1.70 | 8.3 |
| NT06 | Tai Po | 147.8 | 172 | 1.0 | 0.66 | 3.3 |
| NT07 | Sha Tin | 68.3 | 824 | 1.3 | 1.85 | 2.1 |
| NT08 | Sai Kung | 135.9 | 181 | 3.8 | 2.79 | 9.3 |
| NT09 | Islands | 174.7 | 47 | 3.0 | 1.69 | 21.6 |
| Whole Territory Total | | 1096.6 | 681 | 22.7 | 2.07 | 3.4 |

## METHODS

The built environment, especially the green spaces, where older people live plays an important role in promoting or inhibiting physical activity. This study aims to explore the role of neighbourhood green space in determining physical walking activity among elderly residence.

**(1) Normalized Difference Vegetation Index (NDVI)**
Normalized difference vegetation index map in Figure 3 were derived using the following equation:

$$\mathbf{NDVI} = \frac{\boldsymbol{R_{NIR} - R_{red}}}{\boldsymbol{R_{NIR} + R_{red}}} \quad (1)$$

where $\boldsymbol{R_{NIR}}$ and $\boldsymbol{R_{red}}$ are the spectral reflectance in the TM and ETM+ red and near-infrared bands. This NDVI equation produced values in the range from -1 to1, where positive values indicate vegetated areas and negative values signify non-vegetated surface features such as water, barren, clouds, and snow (Yuan & Bauer, 2007). Negative values of NDVI indicate water. Values below 0.1 but above 0 correspond to barren areas of rock, sand or snow. Values between 0.2 and 0.3 represent shrub and grassland, while higher values indicate denser green leaves (e.g. temperate and tropical rainforests). In this study, the neighbourhoods are defined radial buffers around an individual's household, in which the different radius ranging from 100m to 2000m with 100m interval are adopted. It has a value range between −1 and +1.

This study used the assessment to evaluate the characteristics of the neighbourhood green space: the quantity of green space and the quality of vegetation. variation in neighbourhood vegetation. Two measures are based on the NDVI (Gong, Gallacher, Palmer, & Fone, 2014; Van Dillen, de Vries, Groenewegen, & Spreeuwenberg, 2012). The quantity of green space defines the greenness ratio, and the quality of green space expresses the value of NDVI, and the variation in vegetation.

Based on 2011 NASA Landsat 7 science data user's handbook, The variation of vegetation is derived from the standard deviation of NDVI value for all green space within each neighbourhood. This value is evaluated by the type of vegetation, such as grass fields, shrub, trees, woodland and forest. High levels of variation in vegetation characterize mixed vegetation within the neighbourhoods for individual household.

**(2) Physical Activity Scale of the Elderly (PASE)**
In this study, data for the physical walking activity are obtained from a prospective cohort study of 4,000 older people (2,000 males and 2,000 females) in Hong Kong between 2001 and 2009. The total number of subjects from 11/18 districts with ≥100 participants was 3611 (90.3% of the original sample). After four years of follow up, 233 participants had died (Woo, Chan, Leung, & Wong, 2010). From this comprehensive prospective cohort database, we have gained insight on many ageing related physical health problems and calculated Physical Walking Activity Index of subjects.

Physical activity level was assessed using the Physical Activity Scale of the Elderly (PASE). This is a 12-item scale measuring the average number of hours per day spent in leisure, household and occupational physical activities over the previous 7 day-period, and had been

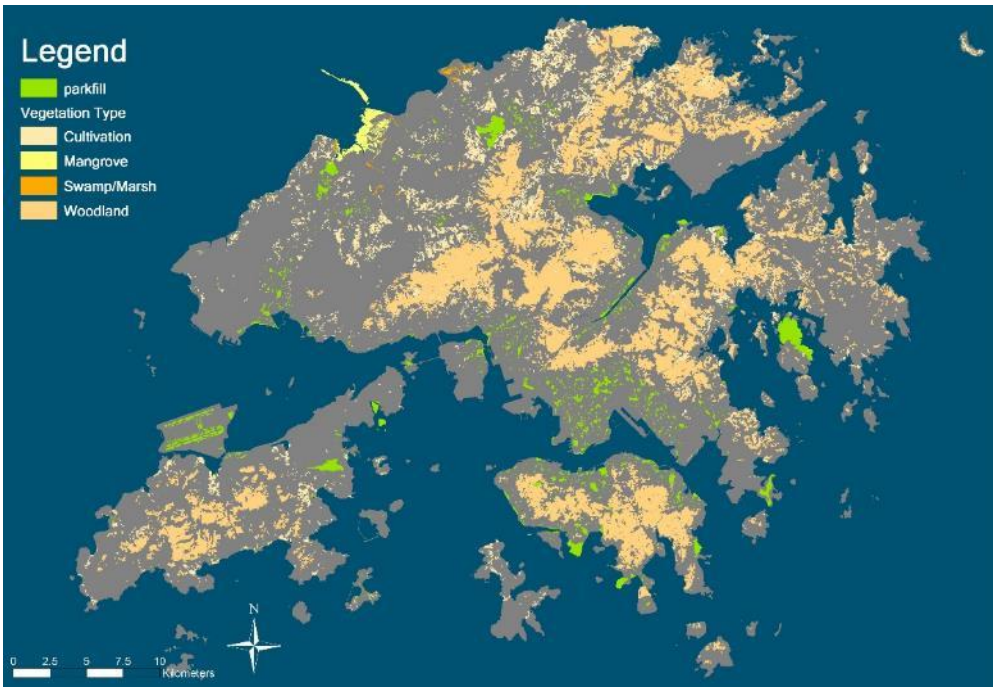


*Figure 2: Greenness distribution in Hong Kong, and the urban green parks (in green) which are publicly accessible.*

used previously in other epidemiological studies in Hong Kong (Chan, Chan, & Woo, 2014; Liu et al., 2001; Washburn, Smith, Jette, & Janney, 1993). 7 day-period, and had been used previously in other epidemiological studies in Hong Kong. In this study we use the physical walking activity data.


*Figure 3: Normalized Difference Vegetation Index (NDVI) in 15m resolution from SPOT satellite in Hong Kong.*

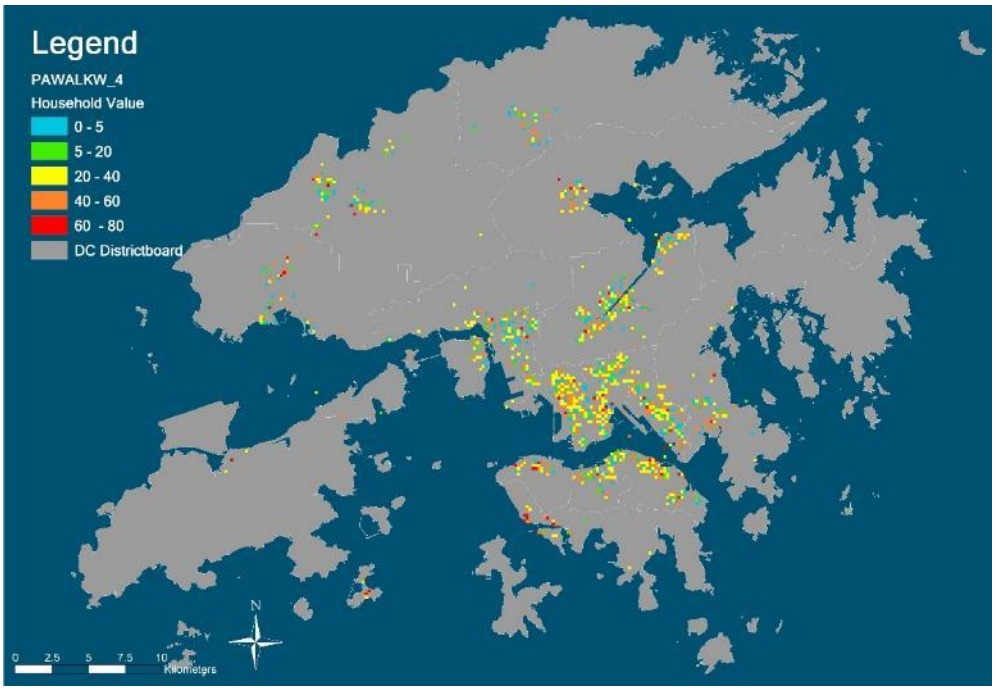


*Figure 4. Distribution of the 4000 people in cohort study and the value of physical walking activity index averaged over the 200x200m grids.*

Activity weights for each item were determined based on the amount of energy expended, and each item score was calculated by multiplying the activity weight by activity daily frequency. A summary score of all the items reflected the daily physical activity level (Woo et al., 2010). In this study PASE sub-score, PAWALKW is the condition of walking actives, which reflected the daily physical activity level of elder people for outdoor environment.

## RESULTS

### (1) Distribution of Green Space

Urban green spaces (UGS) refer to green spaces in parks and other natural areas in cities. They are of a strategic importance for the quality of life in increasingly urbanized society (Chiesura, 2004; Lee & Maheswaran, 2010; Van Cauwenberg et al., 2011). Based on standards of Hong Kong Planning Standards and Guidelines (HKPSG) produced by the government (Planning Department, 2003). UGS are classified into five categories: open spaces, green belts, conservation areas, country parks and coastal protection areas (Chapter 4 and 10, HKPSG).

From Figure 2, there are 2,935 patches (publicly accessible urban parks) in Hong Kong, including more than 50% green patches which are smaller than 0.01 $km^2$. The density of green space patch is 22.9 patches per $km^2$ in Hong Kong. Overall, the degree of fragmentation and green space patch density are high in Hong Kong, and the distribution pattern of green space is mainly characterized by small in size and scattered in spatial distribution.

Figure 3 shows distribution of NDVI from space in Hong Kong. Although more than half of the land regions are covered by vegetation, what can be mostly accessible by elderly people in high density city are urban green parks. In particular, trees which have a larger cooling effect compared to grass will be more preferable to elderly people. In this study, the trees and grass are separated using NDVI based on supervised classification. Neighbourhood green spaces based on radial buffering with different radius are extracted for trees and grass, separately.

### (2) Physical Walking Activity of the Elderly

The distribution of the 4000 people in the cohort study and the value of their physical walking activity are shown in Figure 4. We can see that the study has samples has uniform distribution in all the main residential areas in Hong Kong. Refer to Figure 5, the most frequency of PAWALKW score is 0-10 and 20-30, at the same number, and both are over 1300 senior residences; Although there are few elderly people got the high score at 30-50 and 50-80. However, there are more than 1000 elder had the PAWALKW score at 50-60, which evaluates their good condition for the daily physical walking activity.

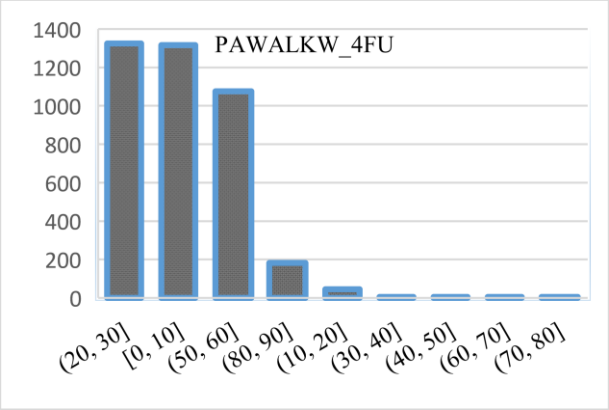


*Figure 5: Population Distribution of the Physical Activity Scale of the Elderly (PASE sub-score, PAWALKW) in Hong Kong (x: sub-score of PASE Index, y-the population proportion of elderly people).*

### (3) Association Analysis Between Elderly Physical Activity and Neighbourhood Green Space

Table 2 shows the result from linear regression between neighbourhood trees ratio (quantified as area ratio of tree to whole buffer area calculated from NDVI data) and physical walking activity.

The results of slope of walking activity to neighbourhood tree ratio and the corresponding p-value from linear regression are included. The bold values are the cases with significant correlation between the neighbourhood tree ratio and walking activities ($p<0.1$). From the regression results, we can see that, positive correlations exist for most of the cases, suggesting that, as the neighbourhood tree ratios increase, the physical walking activities by elderly people will also increase.

This positive correlation is significant when the buffer radius is larger than 1200 meter, indicating green space in large neighbourhoods plays a key role in encouraging elderly to walk more. These results illustrate the necessity for improving elderly health in high density and aging society via increasing neighbourhood green space in both near and far-away neighbourhoods. Same experiment is also implemented for neighbourhood grass, but the correlation is not significant as for neighbourhood trees. These results suggest that neighbourhood trees in high density city have a higher impact in promoting physical walking activities for elderly people.

*Table 2: regression results from correlation between neighbourhood green space and physical walking activity of elderly people in Hong Kong. The slope and p-value from t-test are included for different buffer radius of the neighbourhood tree ratio.*

| Neighbourhood tree ratio buffer radius (km) | Slope (Walking/NDVI) | p-value |
|---|---|---|
| 100 | -0.14 | 0.99 |
| 200 | 2.40 | 0.76 |
| 300 | -0.52 | 0.94 |
| 400 | -0.48 | 0.95 |
| 500 | 0.09 | 0.99 |
| 600 | 0.56 | 0.93 |
| 700 | 2.72 | 0.67 |
| 800 | 4.74 | 0.44 |
| 900 | 6.06 | 0.30 |
| 1000 | 7.10 | 0.20 |
| 1100 | 8.07 | 0.13 |
| 1200 | 8.75 | 0.09 |
| 1300 | 9.13 | 0.06 |
| 1400 | 9.36 | 0.04 |
| 1500 | 9.55 | 0.03 |
| 1600 | 9.43 | 0.03 |
| 1700 | 9.33 | 0.03 |
| 1800 | 9.16 | 0.02 |
| 1900 | 9.05 | 0.02 |
| 2000 | 8.84 | 0.02 |

## CONCLUSION AND FUTURE STUDY

The aim of this study is to explore the association between neighbourhood green space and elderly physical activity in Hong Kong, a typical high density and aging city in the world. In general, we find that (1) elderly living in neighbourhoods with more green space have higher levels of participation in regular physical walking activities, (2) significant correlation can be observed between neighbourhood green space with radius larger than 1200m and regular physical walking activity, indicating green space in large neighbourhoods plays a key role in encouraging elderly to walk more. These results illustrate the necessity for improving elderly health in high density and aging society via increasing neighbourhood green space in both near and far-away neighbourhoods. This provides a basis for urban planning policy to design and encourage the use of neighbourhood green space. A limitation of this study is that controlling for demography and social-economic data are not considered. Since the cohort study has large number of samples from different class, we expect the effects of demography and social-economic data should not affect our conclusions.

The future study will more focus on how to improve the planning and design of urban neighbourhood green spaces to improve the elderly's physical and mental health in high density cities like Hong Kong. To build a platform for commination and cooperation among policy makers, urban planners/designers, and public health scientists to making urban planning strategies for creating a future healthy and ageing-friendly city.

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