Peer-reviewed version available at *Int. J. Environ. Res. Public Health* **2019**, *16*, 1514; doi:10.3390/ijerph16091514

Article

Promoting Exercise in Urban Area: Importance of Green Space and Facility Accessibility

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Abstract: 1) Background: A population-based cross-sectional study was conducted to understand how green cover and accessibility of common public open spaces in compact urban areas affect physical activeness of resident. 2) Methods: A total of 554 residents completed a structured questionnaire on quality-of-life, physical activity level, and healthy eating practice. 3) Results: The sampled population lived with green cover averaged 10.11±7.95% (ranged 1.56-9.88), whereas majority (90%) of the residents performed physical activities at medium and high levels. Metabolic Equivalent of Task (MET)-minutes/week was associated with the green cover percentage (Pearson $r=0.092$; $p<0.05$). Irrespective of age and physical activity level, active residents commonly used public open spaces within district for performing exercise, especially parks and promenade were mostly used by older residents while sports facilities by the younger groups. 4) Conclusions: Current findings suggested promotion of exercise could be achieved by the design or redesign of built environment to include more parks accessible to the residents with the increase of vegetation.

Keywords: Physical activity; exercise; green cover; open space; Metabolic Equivalent of Task; International Physical Activity Questionnaire; health promotion

1. Introduction

Physical activity and healthy eating are the two important aspects of a healthy lifestyle that is preventing premature mortality and most of the chronic illnesses [1-3]. The World Health Organization recommended at least 150 minutes of aerobic physical activity at moderate-intensity, corresponding to 3-6 Metabolic Equivalents of Task (METs) per week for adults at age between 18 and 64 years, in order to improve cardiorespiratory and muscular fitness, bone health, reduce the risk of non-communicable diseases and depression [4]. According to the Hong Kong Cardiovascular Risk Factor Prevalence Study, 59% of local adults were living with sedentary lifestyle who did no sport or exercise over a month, whereas only one-third performed at least 20 minutes of sustained vigorous exercise on at least 3 days per week [5]. Specifically, three out of four Hong Kong residents had not participated a substantial level of physical activity with 36.1% being not active at all and 40.2% being somewhat active [6]. Despite there was 20-25% of adults who exercised at least 4 times per week, more than half of the local population were reported to have no leisure time of physical activity over

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a 10-year period while 20.6% of all-cause deaths were attributable to not exercising [7]. Leisure-time physical activity was demonstrated to have protective effects on mortality with adjusted odds ratios of 0.63 for men and 0.75 for women [7]. In an international study involving 20 countries, the reported local prevalence of 'low active' (i.e. less than 600 MET-minutes per week) was contradictorily low at 15.3% for the population at age 20-64 years [8]. However, results of the recent Behavioral Risk Factor Survey 2016 indicated that almost half (43.8%) of the Hong Kong's adults had met the physical activity level recommended by the WHO while 18.5% and 21.1% of the studied population had a Body Mass Index (BMI) being classified as overweight and obese, respectively [9]. Besides physical activity, the same study also reported the dietary patterns of the participants who consumed 3.4 servings of fruits and vegetables per day while three-fourths (73.7%) of them consumed more than 4 taels of meat per day [9]. It is well established that sedentary life together with excess energy intake lead to the consequence of obesity, which is the major risk factor for premature mortality and many chronic problems, including cardiovascular diseases [10;11], diabetes [12;13], and cancers [14;15]. In addition to physical inactivity, the high prevalence of obesity in Hong Kong was believed to be associated with the typical unhealthy dietary pattern of many developed societies characterized by energy dense processed food typically high in fat, protein and refined carbohydrates with a low fibre content [16]. Obesity was seemed to be promoted by the intake of variety of snacks while such developed could be reversed by the intake of variety of grains and meats [17]. Additional contributing factors for obesity included sleeping and working hours [18] as well as night shift work [19]. Whilst people with a higher education level was prone to have healthier diet that led to low overweight prevalence [20].

Accumulating evidence has suggested that there is a relationship between green space and health [21-24]. The systematic review of Lachowycz and Jones [21] identified inconsistent and mixed evidence on the positive impacts of green space toward obesity-related health indicators; however, the relationships between green space and physical activity were controversial. A study conducted in Netherlands has correlated a lower prevalence of coronary heart disease and diabetes with green space [25]. Maas and collogues [22] have proposed physical activity as the possible mechanism underlying the relationship between green space and health, but such relationship has not yet established because positive correlation was only identified between duration of cycling and gardening by the multilevel analysis. According to the Danish national representative survey, a better health-related quality of life (HRQoL) was observed when an individual was living closer a distance from green space [26]. Green space can be defined by one of the two interpretations: 1) refers to bodies of water or areas of vegetation in a landscape, which can be an antonym of urbanization; and 2) represents urban vegetation that is relating to a vegetated variant of open space [27]. Urban green spaces including park and public recreation facilities benefit the general public health through promoting physical activity and psychological well-being among urban residents [23]. Hong Kong is a compact city with most of its 7 million population living in the urban areas at medium to high density. Despite the whole territory of Hong Kong has a higher percentage of green cover (51.2%) as compared with the nearby main cities in China, most of these are woodland and shrub land located at the countryside that are inaccessible to urban residents [28]. In fact, the green spaces in high-density areas of Hong Kong are totally fragmented while a small proportion of greens may be accessible to some medium-density areas (especially those newly developed areas on reclaimed land), whereas the overall open space-to-total space ratio is approximately 10% [29]. Our recent QoL study demonstrated different levels of satisfaction with physical environment and open spaces among the residents of nine districts of Hong Kong at medium-to-high density, and around 60% of the studied population had sometime or always participated healthy eating with low fat, low sodium and low sugar while 62.9% performed moderate physical activity regularly [30]. Therefore, we are particularly interested in further understanding how such healthy lifestyle practices are associated with the urban green space. In this study, a population-based survey was conducted to understand the relationships between green cover and healthy lifestyle, particularly in physical activity levels and dietary habits in the nine urban residential areas of Hong Kong. Secondarily, the usage of common facilities accessible to the residents and their characteristics would also be explored.

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2. Materials and Methods

2.1. Target Population and Recruitment

The current studied population consisted of an existing dataset expanded by continuing the recruitment of residents from the nine district council constituency areas of Hong Kong that covered mixed-use commercial and residential districts, old urban and more affluent districts with different housing types, and people with various socio-economic status [30]. Adult residents aged at least 20 years and had been living in any of the nine districts for more than one year were the target population. Those who were cognitively impaired, unable to communicate effectively in Cantonese, Mandarin and English or having physical immobility that limits their physical activity were excluded. Convenience sampling method was used for recruiting the participants of this cross-sectional study. In brief, well-trained interviewers were allocated at parks, resting areas and outside food markets and shopping centres in the nine district areas from 9 am to 7 pm on weekdays and weekends to capture all types of residents. A verbal consent was obtained from each of the participant after confirming the eligibility and explaining the purpose of the study. The answered questionnaire and the signing for the token of appreciation were also the implied consent to participant in this study. The whole procedure took around 15 minutes to complete. A supermarket shopping voucher (HKD 50 value) was given to each of the participants at the end as an incentive. Ethical approval (Reference: HSEARS20170825001) was obtained from the Human Subjects Ethics Committee of the Hong Kong Polytechnic University.

2.1. The Instrument and Measurements

The structured instrument used in this study was composed of four major parts. First, the socio-demographic profiles of the residents were assessed. Second, the validated 26-item "Hong Kong version of WHOQOL-BREF " questionnaire were used to assess the four domains of QoL perception, namely physical, psychological, social and environment with 24 items, in addition to two individual items on general health and overall QoL [31]. The domain scores were transformed into a linear scale between 0 and 100 following the scoring guideline. Third, the Chinese version of the International Physical Activity Questionnaire short form (IPAQ-C) was used for assessing the physical activity levels of the residents [32]. Participants were asked on number of days in the past 7 days prior to the survey and daily time performing walking (as low-intensity), moderate and vigorous activities. The total MER-total/week was calculated and physical activity levels were categorized as low, medium and high, based on the scoring guidelines. Individuals who failed to answer all items of the IPAQ-C were removed from the analysis. Lastly, the healthy eating practice (low sugar, low salt, low fat) was measured on a 4-point Likert scale (1 = never; 4 = always), in addition to the fruit and vegetable intakes. Individual adults are recommended to consume at least two portions of fruit and three portions of vegetable per day [33]. Additionally, the usage of parks, promenade, outdoor and indoor sports facilities within and nearby the residential district of participants were also assessed, in terms of frequency and duration. Furthermore, as an objective measure of green space within a defined area, the green cover % was estimated based on the vegetation and wetland surrounding the 500m radius of each participant's residential address. The residential green cover of current studied population ranged 1.47-33.89%, which was categorized at equal proportion into low (1.47-11.94%), medium (11.95-22.42%) and high (22.43-32.89%) levels according to the green coverage (Table 1).

2.1. Data Processing and Analysis

Data collected was analyzed using IBM SPSS Statistics 25.0 (Armonk, NY). Participants were categorized into three subgroups according to the green cover % of their residential addresses. Descriptive statistics (frequency and percentages) were used to describe the socio-demographics, the IPAQ levels, and other categorical variables. Continuous variables and scores were summarized as mean and standard deviation (SD). Chi-squared test was used to compare nominal variables, whereas

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146 student's t-test and one-way ANOVA test were used for comparison of mean values between two
147 groups and among multiple (>2) groups, respectively. Linear correlation between two variables was
148 evaluated using the Pearson's correlation analysis.
149
150

Table 1. Demographics

Variables		Total	Green Cover Levels			χ^2 test† or one-way ANOVA
			Low	Medium	High	
		N=554	N=338	N=135	N=81	
		Frequency (Percentage)				
Green cover (%)	Mean±SD, range	10.11±7.95, 1.56-32.90	4.38±1.90, 1.56-9.88	16.12±3.25, 10.16-19.62	24.05±2.69, 20.02-32.90	F=2722.80; p<0.001
Age (year-old)	<25	101 (18.23)	47 (13.91)	47 (34.81)	7 (8.64)	p=0.001†
	25-44	165 (29.78)	105 (31.07)	39 (28.89)	21 (25.93)	
	45-64	132 (23.83)	90 (26.63)	26 (19.26)	16 (19.75)	
	≥65	156 (28.16)	96 (28.40)	23 (17.04)	37 (45.68)	
	Mean±SD	48.05±20.98	49.53±20.45	39.90±20.14	55.47±20.60	F=17.02; p<0.001[a]
Gender	Male	198 (35.74)	117 (34.62)	52 (38.52)	29 (35.80)	p=0.726†
Marital status	Single	168 (30.32)	87 (25.74)	64 (47.41)	17 (20.99)	p=0.001†
	Married	339 (61.19)	223 (65.98)	63 (46.67)	53 (65.43)	
	Divorced/ widowed	47 (8.48)	28 (8.28)	8 (5.93)	11 (13.58)	
Years been living in current district		15.19±14.09	15.31±13.95	11.27±13.32	21.62±13.65	F=14.32; p<0.001[b]
Housing type	Self-owned	303 (54.69)	218 (64.50)	60 (44.44)	25 (30.86)	p<0.001†
	Rental	251 (45.31)	120 (35.50)	75 (55.56)	56 (69.14)	
Living status	Alone	58 (10.47)	33 (9.76)	19 (14.07)	6 (7.41)	p<0.001†
	With someone	496 (89.53)	305 (90.24)	116 (85.93)	75 (92.59)	
Household size	Mean±SD	3.21±1.61	3.53±1.64	2.77±1.44	3.30±1.63	F=7.369; p=0.001[c]
Educational level	≤Primary	109 (19.68)	67 (19.82)	13 (9.63)	29 (35.80)	<0.001†
	Secondary	166 (29.96)	101 (29.88)	38 (28.15)	27 (33.33)	
	≥College	278 (50.18)	170 (50.30)	83 (61.48)	25 (30.86)	
Monthly income (HKD)	No income	247 (44.58)	146 (43.20)	58 (42.96)	43 (53.09)	p=0.020†
	≤10500	126 (22.74)	69 (20.41)	36 (26.67)	21 (25.93)	
	10501-14800	48 (8.66)	34 (10.06)	10 (7.41)	4 (4.94)	
	14801-23000	48 (8.66)	24 (7.10)	17 (12.59)	7 (8.64)	
	≥23001	85 (15.34)	65 (19.23)	14 (10.37)	6 (7.41)	
WHOQOL scores	Physical	60.89±1032	60.67±10.38	59.45±9.97	64.20±10.54	F=5.64; p=0.004
	Psychological	62.92±13.56	63.41±13.23	60.68±14.33	64.61±13.28	F=2.72; p=0.067
	Social	62.69±12.52	63.16±12.41	61.03±13.97	63.54±10.05	F=1.61; p=0.200
	Environmental	62.15±13.57	62.91±12.21	58.92±14.55	64.56±12.51	F=5.97; p=0.003

151

152 **3. Results**

153 *3.1. Socio-demographics and living enviroment of participants*

154 A total of 554 participants had completed the questionnaire. The mean green cover within 500m
155 radius of participants' residential address was 10.11% (SD=7.95%), and many of the socio-
156 demographic variables and WHOQoL scores were significantly different among the discrete
157 subgroup levels (low, medium, and high) of green coverage (Table 1). Majority of the studied

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158 population (61.0%) was living at an environment with low green coverage ranged at 1.56-9.88% with
159 the largest household size at 3.53±1.64 people but the highest monthly incomes, whose ages were
160 evenly distributed with half graduated at college or above, two-third married and lived at self-owned
161 housing (Table 1). In contrast, only 14.6% of the studied population was living with high green
162 coverage was the oldest subgroup with 45% that had reached the retirement age (≥65 years) with the
163 lowest incomes and lived the longest at the present address for 21.62±13.65 years with the majority
164 living with family at household size of 3.30±1.63 people (Table 1). The profile of "high" green cover
165 subgroup matched with the majority (almost 70%) who were living in the rental type of housing,
166 which was presumably public housing that was constructed by the government to provide
167 considerable green cover with outdoor space and facilities. Nonetheless, among the 3 subgroups, the
168 "medium green cover" was found to be the youngest and highest educated with moderate incomes,
169 the smallest household size with almost half being single, and 14.07% living alone (Table 1). This
170 "medium green cover" subgroup was seemed to be formed by approximately half-and-half rental
171 and self-owned housing. Among the 3 subgroups, the "high" and "medium" green covered
172 participants perceived the best and poorest Quality of Life (QoL) in all 4 domains (Table 1).
173
174 **Table 2.** Physical activities and dietary habits of participants living with different green cover
175 levels.

Variables		Total	Green Cover Levels			
			Low	Medium	High	One-way ANOVA
		N=554	N=338	N=135	N=81	
Physical activities				Mean±SD		
MET-minutes/week	Total	2421.80 ±1785.51	2285.70 ±1649.69	2505.50 ±1874.95	2850.25 ±2105.61	F=3.49; p=0.031
				Frequency (Percentage)		χ^2 test
IPAQ levels	High	179 (32.31)	94 (27.81)	53 (39.26)	32 (39.51)	p=0.064
	Moderate	319 (57.58)	210 (62.13)	67 (49.63)	42 (51.85)	
	Low	56 (10.11)	34 (10.06)	15 (11.11)	7 (8.64)	
Dietary habits						
Fulfillment of 2 servings of fruits + 3 servings of vegetables		32 (5.78)	24 (7.10)	5 (3.70)	3 (3.70)	p=0.247
Fruit consumption (serving per day)	≥2 servings	90 (16.25)	59 (17.46)	20 (14.8)	11 (13.58)	p=0.019
	1 serving	212 (38.27)	135 (39.94)	37 (27.41)	40 (49.38)	
	<1 serving	231 (41.70)	133 (39.35)	72 (53.33)	26 (32.10)	
	None	21 (3.79)	11 (3.25)	6 (4.44)	4 (4.94)	
Vegetable consumption (serving per day)	≥3 serving	54 (9.75)	37 (10.95)	9 (6.67)	8 (9.88)	p=0.066
	1-2 serving	340 (61.37)	215 (63.61)	72 (53.33)	53 (65.43)	
	<1 serving	158 (28.52)	85 (25.15)	53 (39.26)	20 (24.69)	
	None	2 (0.36)	1 (0.30)	1 (0.74)	0 (0.00)	
Low fat consumption	Often	166 (29.96)	103 (30.47)	33 (24.44)	30 (37.04)	p=0.017
	Sometimes	270 (48.74)	176 (52.07)	67 (49.63)	27 (33.33)	
	Seldom	118 (21.30)	59 (17.46)	35 (25.93)	24 (29.63)	
Low sodium consumption	Often	169 (30.51)	105 (31.07)	33 (24.44)	31 (38.27)	p=0.037
	Sometimes	263 (47.47)	170 (50.30)	65 (48.15)	28 (34.57)	
	Seldom	122 (22.02)	63 (18.64)	37 (27.41)	22 (27.16)	
Low sugar consumption	Often	186 (33.57)	119 (35.21)	35 (25.93)	32 (39.51)	p=0.005
	Sometimes	247 (44.58)	28 (8.28)	59 (43.70)	6 (7.41)	
	Seldom	121 (21.84)	59 (17.46)	41 (30.37)	21 (25.93)	

176 *3.2. Green cover was association with the physcial activity level of participants*

177 Physical activity of the studied population was measured in terms of MET-minutes/week and
178 IPAQ levels. As shown in Tables 2 and 3, the MET-minutes/week was increasing with the increased
179 levels of green cover ($p<0.031$), although the correlation coefficient was weak at 0.092 ($p<0.05$).
180 Regarding the IPAQ levels, the "medium" and "high" green cover subgroups were more trended to
181 perform moderate-to-high levels of physical activity while the physical activity levels of those living

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with low green cover were mainly at moderate level (Table 2). Besides the green cover, both the MET-minutes/week and IPAQ level were weakly correlated with the physical (r-0.11-0.13; $p<0.01$) and psychological (r=0.10-0.12; $p<0.05$) domains of WHO-QoL scale (Table 3). Demographically, weak correlations were only identified between the MET-minutes/week and education level (r=0.092; $p<0.05$) positively but monthly income (r=-0.102; $p<0.05$) negatively (Table 3).

On the other hand, participants living with both green cover extremities were demonstrated to have similar dietary habits, which adopted in general the healthy style of low in fat, sodium and sugar consumption and a high vegetable and fruit content (Table 2). However, the dietary habits of the 'medium green cover' subgroup were relatively unhealthy with majority eating < 1 serving of vegetables (58%), <1 serving of fruits (40%), and at least one-fourth (25.93-30.37%) of them seldom adopted low fat, low sodium, and low sugar diets (Table 2). Unlike physical activity, the green cover of the participants' residency was not correlated with the healthy dietary habits, except for the high vegetable consumption that was negatively significantly correlated (r=-0.087; p=0.041) (Table 3). Whilst many of the dietary habit components were correlated with different demographic and WHO-QoL variables (Table 3).

3.3. Accessibility of outdoor open space facilities in the residential district promotes exercise

To understand how the major open spaces (parks and promenade) and sports facilities (outdoor and indoor) within and at nearly districts were used by the residents who had performed significant levels of physical activities, only participants with high and moderate IPAQ levels (representing 90% of the entire population studied) were remained for further analyzed. The MET-minutes per week values were significantly ($p<0.001$) varied among different age groups of the active participants, with the highest at age 45-64, followed by age ≥65 then age <25 and 25-44 (Table 4). Parks with district were the most frequent open space facility being used by up to 54% of active daily users, whereas both the frequency and duration of usage were increased linearly with age (Table 4). Up to 35% of younger residents used the promenade within district on weekly basis, but most of the daily users were those at older age with 7.5% at age 45-64 and 14.4% at age ≥65 while the duration of usage also followed the linear increasing trend with age (Table 4). Regarding the sports facilities, irrespective of indoor or outdoor, they were prompted to be used more frequently at longer duration by the younger age groups (Table 4). On the contrary, only around 10% of all ages of active participants travelled at 2-4 times per week frequency to the facilities of nearby districts for spending less an hours per month on average, although significant variations ($p<0.01$) were observed among different age groups (Table 4). However, the participants at high IPAQ level were living with significantly higher ($p<0.01$) residential green cover than those of moderate level (Table 5). Those higher physical activity residents were shown to use more frequently and longer the duration than the moderately active counterparts for all facilities within district as well as at nearby districts (Table 5). Current results suggested that, irrespective of age (Table 4) and physical activity level (Table 5) of participants, active residents used predominantly the facilities within their districts, whereas the green cover was also shown to be a promoting factor for performing exercises.

Table 3. Correlational analysis among variables measured in the studied population.

Variables		Dietary habits					Physical activity		WHO-QoL scores				Demographics			
		Low sugar	Low salt	Low fat	High veg	High fruit	IPAQ level	MET-hr	Envir	Social	Psy	Phy	MI	Edu level	HH size	Age
		Pearson correlation coefficient (r); p-value														
Green Cover %		-0.083; 0.051	-0.077; 0.071	-0.074; 0.084	**-0.087; 0.041**	-0.077; 0.069	0.077; 0.071	**0.092; 0.030**	-0.023; 0.588	-0.056; 0.187	-0.029; 0.496	0.055; 0.199	**-0.131; 0.002**	-0.051; 0.227	-0.047; 0.268	-0.042; 0.325
Demographics	Age	**0.229; <0.001**	**0.288; <0.001**	**0.252; <0.001**	**0.228; <0.001**	**0.169; <0.001**	0.049; 0.247	0.059; 0.165	0.026; 0.537	-0.052; 0.223	-0.021; 0.630	0.046; 0.283	**-0.308; <0.001**	**-0.722; <0.001**	-0.044; 0.296	
	HH size	0.073;0.086	0.066; 0.122	0.040; 0.342	**0.155; <0.001**	**0.110; 0.009**	0.065; 0.124	0.082;0.055	0.028; 0.505	**0.105; 0.013**	**0.153; <0.001**	0.072; 0.091	-0.069; 0.103	0.000; 1.000		
	Edu level	**-0.154; <0.001**	**-0.186; <0.001**	**-0.143; 0.001**	**-0.160; <0.001**	**-0.136; 0.001**	-0.072; 0.089	**-0.092; 0.031**	**0.094; 0.027**	0.063;0.138	**0.090; 0.033**	-0.033; 0.444	**0.403; <0.001**			
	MI	-0.035; 0.416	-0.073; 0.086	-0.072; 0.090	**-0.139; 0.001**	-0.045; 0.290	-0.071; 0.094	**-0.102; 0.017**	0.016;0.716	0.038; 0.369	0.048; 0.256	-0.026; 0.540				
WHO-QoL scores	Phy	0.108; 0.011	**0.088; 0.038**	0.050; 0.243	**0.198; <0.001**	**0.162; <0.001**	**0.133; 0.002**	**0.111; 0.009**	**0.503; <0.001**	**0.450; <0.001**	**0.627; <0.001**					
	Psy	0.073; 0.087	0.047; 0.266	0.029; 0.489	**0.187; <0.001**	**0.214; <0.001**	**0.097; 0.023**	**0.124; 0.003**	**0.608; <0.001**	**0.506; <0.001**						
	Social	**0.095; 0.026**	**0.105; 0.013**	0.066; 0.120	**0.175; <0.001**	**0.112; 0.008**	0.039; 0.361	0.024; 0.573	**0.436; <0.001**							
	Envir	**0.128; 0.003**	0.077;0.070	0.060; 0.156	**0.111; 0.009**	**0.182; <0.001**	0.044; 0.303	0.039; 0.363								
Physical activity	MET-min	0.002; 0.970	0.009; 0.831	-0.007; 0.877	**0.213; <0.001**	**0.167; <0.001**	**0.806; <0.001**									
	IPAQ level	-0.002; 0.966	0.001; 0.980	-0.015; 0.727	**0.245; <0.001**											
Dietary habits	High fruit	**0.203; <0.001**	**0.251; <0.001**	**0.243; <0.001**	**0.560; <0.001**											
	High veg	**0.271; <0.001**	**0.299; <0.001**	**0.294; <0.001**												
	Low fat	**0.836; <0.001**	**0.893; <0.001**													
	Low salt	**0.846; <0.001**														

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226 **Table 4.** The usage of within and nearby district facilities by active participants of different age
227 ranges.

Variables		Age Group				χ^2 test† or one-way ANOVA
		<25	25-44	45-64	≥65	
		n=86	n=146	n=120	n=146	
MET-minutes per week	Mean±SD	4326±1398	4031±1188	5118±1631	4728±1245	F=5.799; p=0.001
		Number (Percentage)				
Usage of facilities – Within district						
Parks	<Once a mth	60 (69.8)	57 (39.0)	41 (34.2)	16 (11.0)	p<0.001†
	2-4 per mth	19 (22.1)	33 (22.6)	31 (25.8)	11 (7.5)	
	>Once per wk	7 (23.3)	34 (23.3)	25 (20.8)	40 (27.4)	
	Daily	0 (0.0)	22 (15.1)	23 (19.2)	79 (54.1)	
	Hours used per month, mean±SD	1.91±4.90	13.64±30.53	17.22±34.42	41.14±42.83	F=30.28; p<0.001
Promenade	<Once a mth	48 (55.8)	80 (54.8)	66 (55.0)	90 (61.6)	p<0.001†
	2-4 per mth	30 (34.9)	47 (32.2)	30 (25.0)	21 (14.4)	
	>Once per wk	7 (8.1)	18 (12.3)	15 (12.5)	14 (9.6)	
	Daily	1 (1.2)	1 (0.7)	9 (7.5)	21 (14.4)	
	Hours used per month, mean±SD	2.33±3.70	3.28±7.71	6.50±21.22	8.86±19.45	F=4.669; p=0.003
Outdoor sports facilities	<Once a mth	71 (82.6)	109 (74.7)	102 (85.0)	126 (86.3)	p<0.001†
	2-4 per mth	12 (13.9)	23 (15.8)	14 (11.7)	6 (4.1)	
	>Once per wk	3 (3.5)	11 (9.6)	4 (3.3)	4 (2.7)	
	Daily	0 (0.0)	3 (1.4)	0 (0.0)	10 (6.9)	
	Hours used per month, mean±SD	1.67±5.07	3.72±18.24	1.04±3.29	2.44±8.55	F=1.382; p=0.247
Indoor sports facilities	<Once a mth	53 (63.0)	93 (63.7)	98 (81.7)	125 (85.6)	p<0.001†
	2-4 per mth	22 (26.2)	37 (25.3)	16 (13.3)	7 (4.8)	
	>Once per wk	11 (12.8)	14 (9.6)	5 (4.2)	9 (6.2)	
	Daily	0 (0.0)	2 (1.4)	1 (0.8)	5 (3.4)	
	Hours used per month, mean±SD	3.43±7.12	2.88±6.36	1.86±8.16	2.63±11.8	F=0.576; p=0.631
Usage of facilities – Nearby districts						
Parks	<Once a mth	77 (89.5)	107 (73.3)	108 (90.0)	129 (88.3)	p<0.001†
	2-4 per mth	8 (9.3)	37 (25.3)	11 (9.2)	10 (6.9)	
	>Once per wk	1 (1.2)	2 (1.4)	0 (0.0)	4 (2.7)	
	Daily	0 (0.0)	0 (0.0)	1 (0.8)	3 (2.1)	
	Hours used per month, mean±SD	0.41±1.07	1.64±4.64	0.86±6.85	1.80±6.96	F=1.508; p=0.212
Promenade	<Once a mth	76 (88.4)	126 (86.3)	110 (91.7)	143 (97.9)	p=0.010†
	2-4 per mth	10 (11.6)	20 (13.7)	8 (6.7)	2 (1.4)	
	>Once per wk	0 (0.0)	0 (0.0)	1 (0.8)	0 (0.0)	
	Daily	0 (0.0)	0 (0.0)	1 (0.8)	1 (0.7)	
	Hours used per month, mean±SD	0.34±0.81	0.65±1.68	0.77±5.54	0.29±2.51	F=0.673; p=0.569
Outdoor sports facilities	<Once a mth	73 (84.9)	123 (84.2)	109 (90.8)	138 (94.5)	p=0.009†
	2-4 per mth	11 (12.8)	21 (14.4)	10 (8.4)	4 (2.7)	
	>Once per wk	2 (2.3)	2 (1.4)	1 (0.8)	1 (0.7)	
	Daily	0 (0.0)	0 (0.0)	0 (0.0)	3 (2.1)	
	Hours used per month, mean±SD	1.53±5.05	1.83±6.30	0.74±2.87	1.12±6.26	F=0.999; p=0.393
Indoor sports facilities	<Once a mth	76 (88.4)	131 (89.7)	111 (92.5)	145 (99.3)	p=0.020†
	2-4 per mth	8 (9.3)	12 (8.2)	6 (5.0)	1 (0.7)	
	>Once per wk	2 (2.3)	3 (2.1)	3 (2.5)	0 (0.0)	
	Daily	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
	Hours used per month, mean±SD	0.64±1.93	0.59±2.27	0.69±2.90	0.10±0.09	F=3.258; p=0.021

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231 **Table 5.** Comparison of the usage of within and nearby district facilities among moderate and
232 high IPAQ level residents.

Variables.		IPAQ levels		
		Moderate (n=319)	High (n=179)	Student's t-test
		Mean±SD		
Green Cover %		9.38±7.69	11.35±8.41	p=0.008
Age		49.08±21.01	48.12±20.83	p=0.626
Years been living in current district		15.18±13.70	15.31±14.78	p=0.919
HH size		3.13±1.65	3.37±1.67	p=0.112
		Number (Percentage)		χ^2 test† or Student's t-test
Frequency of Facilities usage within district				
Parks	<Once a mth	119 (37.3)	55 (30.7)	p=0.053†
	2-4 per mth	66 (20.7)	28 (15.6)	
	>Once per wk	66 (20.7)	40 (22.3)	
	Daily	68 (21.3)	56 (31.3)	
	Hours used per month, mean±SD	18.11±34.31	24.86±38.56	p=0.045
Promenade	<Once a mth	186 (58.3)	98 (54.7)	p=0.835†
	2-4 per mth	81 (25.4)	47 (26.3)	
	>Once per wk	32 (10.0)	22 (12.3)	
	Daily	20 (6.3)	12 (6.7)	
	Hours used per month, mean±SD	4.76±11.11	6.89±21.44	0.146
Outdoor sports facilities	<Once a mth	274 (85.9)	134 (74.9)	0.020†
	2-4 per mth	29 (9.1)	26 (14.5)	
	>Once per wk	10 (3.1)	12 (6.7)	
	Daily	6 (1.9)	7 (3.9)	
	Hours used per month, mean±SD	1.60±6.07	3.66±16.87	0.050
Indoor sports facilities	<Once a mth	246 (77.1)	123 (68.7)	0.044†
	2-4 per mth	47 (14.7)	35 (19.6)	
	>Once per wk	24 (7.5)	15 (8.4)	
	Daily	2 (0.6)	6 (3.4)	
	Hours used per month, mean±SD	1.89±4.02	4.02±12.76	0.010
Frequency of Facilities usage in nearby districts				
Parks	<Once a mth	277 (86.8)	144 (80.4)	0.113†
	2-4 per mth	36 (11.3)	30 (16.8)	
	>Once per wk	5 (1.6)	2 (1.1)	
	Daily	1 (0.3)	3 (1.7)	
	Hours used per month, mean±SD	0.97±4.32	1.85±7.48	0.096
Promenade	<Once a mth	300 (94.0)	155 (86.6)	0.013†
	2-4 per mth	19 (6.0)	21 (11.7)	
	>Once per wk	0 (0.0)	1 (0.6)	
	Daily	0 (0.0)	2 (1.1)	
	Hours used per month, mean±SD	0.24±0.96	1.03±5.13	0.008
Outdoor sports facilities	<Once a mth	296 (92.8)	147 (82.1)	0.001†
	2-4 per mth	21 (6.6)	25 (14.0)	
	>Once per wk	2 (0.6)	4 (2.2)	
	Daily	0 (0.0)	3 (1.7)	
	Hours used per month, mean±SD	0.73±2.34	2.34±7.67	0.001
Indoor sports facilities	<Once a mth	303 (95.0)	160 (89.4)	0.055†
	2-4 per mth	13 (4.1)	14 (7.8)	
	>Once per wk	3 (0.9)	5 (2.8)	
	Daily	0 (0.0)	0 (0.0)	
	Hours used per month, mean±SD	0.33±0.67	0.67±2.56	0.080

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4. Discussion

The current studied population was formed by residents of typical urban areas that covered by a limited range of vegetation. The physical activity of participants as measured by MET-minutes per week and IPAQ levels were in linear relationships with the green cover percentage. The majority of participants had performed regular exercise at moderate and high levels, and irrespective of age and physical activity level, those active participants used predominantly the facilities within their residential districts but facilities at nearby districts were seldom used. Particularly, parks and promenade were mostly used by older residents while sports facilities by the younger groups. Results suggested open space facility accessibility was an important promoting factor for exercises in compacted urban areas, in addition to the level of green cover. On the other hand, healthy eating habits were not correlated with the green cover but other demographic and QoL variables.

The studied districts areas represented the most compact living environment with the highest population density and lowest green cover, where the green spaces were fragmented and embedded in the built-up urban areas [29]. It also represented a typical lower-to-middle socio-economic class population of Hong Kong, whereas the majority were found to be physically active that have met the WHO's recommendation to perform at least 150 minutes of moderate-intensity exercise in a week [4]. With around 60% and 10% of participants being categorized respectively as having moderate and low physical activity levels, the pattern of this extended study population was consistent with that reported in our previous publication [30]. This also agreed with the results of an international study involving 14 urban cities, where Hong Kong was identified as one of the upper bound range cities with 56% adult residents meeting the 150 min/week guideline who participated on average 44.9 minutes each day on moderate-to-vigorous physical activity [34]. These findings were contradictory to the notion of high physical inactivity of Hong Kong that only one-third of the population had met the WHO guideline [5;6]. The adequate physical activity knowledge among the general population of Hong Kong may explain the behavioral changes in the past two decades [35], which required further elucidation. Current results was also inconsistent with many studies that reported the negative correlation between physical activity participation and socio-economic status among urban living participants [36-38]. In Hong Kong, the government provides public rental housing estates to the low socio-economic population at much affordable cost. Those public housing estates are built with greener and healthier design to provide a considerable recreational spaces for different activities [39], which was in contrast with the private housing that all the shared spaces and facilities are paid by the owners [40]. Therefore, within the compact urban areas, residents of lower socio-economic are not uncommon living in housing with the relatively higher green cover and more shared spaces than the high socio-economic counterparts. On the other hand, it was suggested that higher education level of Hong Kong Chinse population was associated with a healthier diet that leading to lower prevalence of obesity and certain cardiovascular risks [20]. Despite there were statistical significant correlations in this study, higher education levels of participants were associated with poorer dietary habits with lesser consumption of low sugar, low salt, low fat, and high fiber diets. Since the pattern of dietary habits were not correlated with the urban green cover, its inter-relationship with other demographic and QoL factors will be discussed elsewhere.

It is well established that urban green spaces have multiple health benefits, and lower socio-economic groups such as elderly, youth and those less educated were seemed to benefit more from the green areas of their living urban environment [24;41]. The strongest health benefit of greenspace has been related to obesity [21]. Whilst the positive relationship between green cover % and physical activeness identified in this study supported the notion of physical activity as the possible mechanism for the health benefits derived from green spaces [22]. Urban green spaces at neighborhood areas were frequently visited by over 70% of Hong Kong residents, whereas physical exercise and strolling ranked as the top purpose [42]. Besides green cover, numerous studies suggested accessibility to public open spaces was a key environmental determinant affecting the physical activity participation [38;43]. Participations of physical activity among adults in 11 countries were found to be associated with the accessibility of certain built-environment characteristics at the neighborhood with the

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highest odds for sidewalks present [44]. At community level, public spaces and sports facilities serve multiple functions that leading the behavioral choices of different physical activities [42]. Without close access to fitness facility was considered as one of the significant barriers for performing physical activity [45]. Current study identified parks within district as the main public open spaces used by the residents. This was consistent with the positive association between the number of parks and participation of physical activity at moderate and vigorous levels across 14 urban cities including Hong Kong [34]. In addition to accessibility, several other attributes including cleanness, aesthetically appealing, and safeness of parks were perceived by users for encouraging the use across the life-span [46]. Owing to the limitation of cross-sectional design, path analysis will be performed as future study for determining the causal relationship between exercise, green space and facility accessibility.

5. Conclusions

Green cover and accessibility of public open spaces were positively associated with the physical activeness of residents living in old compact urban areas of Hong Kong. This suggest promotion of exercise can be achieved by the design or redesign of built environment to include more parks accessible to the residents with the increase of vegetation.

Author Contributions: The project team share equal contributions. FKYW is the project leader. FYW, LY and FKYW designed the study. JWMY and KKPC wrote the first and subsequent drafts of the manuscript and conducted the data analysis. KLC coordinated the data collection and management. JYS, HCH, MSW, and JYSH represented different disciplines involving in interpretation of the data and revising the manuscript. All authors have read the final manuscript and agreed with the content.

Funding: This study was supported by the Green Deck Project and the Dean's Reserve Fund of the Faculty of Health and Social Sciences, The Hong Kong Polytechnic University.

Acknowledgments: The authors would like to thank Ying-ying Lam and Barry Yu for their assistance in data collection.

Conflicts of Interest: The authors declare no conflict of interest.

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