The association between health and Green Infrastructure accessibility : Seongnam city Newtown vs Oldtown

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Abstract

This study investigates the relationship between green infrastructure (GI) accessibility and health outcomes in Seongnam city, contrasting the effects observed in new and old town sectors. Employing an ordinal regression analysis approach, the research analyzes how the proximity and quality of green spaces influence residents' physical activity and mental health across these diverse urban landscapes. In new towns, well-maintained and strategically located green spaces are found to significantly correlate with increased physical activity and enhanced mental health outcomes. In contrast, in old towns, even basic access to green spaces, irrespective of their quality or type, positively impacts health, suggesting that the mere availability of green areas can be beneficial. The study further delineates the effects of different types of GI—public, semi-public, and private. Notably, semi-public green spaces in old towns are associated with increased walking times, highlighting their role in promoting physical activity. The analysis extends to the implications of GI accessibility on overall life satisfaction, with results indicating that quality green spaces are crucial for improving life quality in urban settings. These nuanced findings underline the importance of incorporating a variety of accessible and high-quality green spaces in urban planning to foster public health. The results advocate for policy adjustments that prioritize the development and maintenance of green infrastructure as a fundamental component of urban health strategy. By addressing the specific needs of different urban areas, these strategies can help mitigate health disparities and enhance the well-being of urban populations. This research offers valuable insights for cities worldwide, demonstrating the pivotal role of green spaces in shaping healthier urban environments.

Keywords: Green Infrastructure Accessibility, Urban Public Health, Physical health(IPAQ), Mental health(PHQ-9), Green Infrastructure Satisfaction

Introduction

The impact of the built environment on health has been proven through numerous studies. Environmental psychology, a field that explores the relationship between human behavior and the physical environment, presents an especially intriguing theory known as environmental perception theory. This theory explains the cyclical relationship where humans design their environment, and then that environment influences humans in return(Wicker, 1979, 2002). In the field of urban design, there has been an attempt to categorize this cyclical relationship according to places and elements, leading to research being conducted in broad categories such as 'land use', 'street environment', 'transport environment', 'parks and green spaces', and 'neighborhood amenities'(Gose et al., 2013; Kim & Yoo, 2019). Behind the idea that cities have accelerated human development, the man-made urban environment, including buildings, has resulted in complex and diverse physical, mental, and psychological diseases

(Jeong-Ho et al., 2013), and the World Health Organization (WHO), in (Kenzer, 1999; Tsouros, 1995) has set three goals: health for all (health equity), development of health policy models, and spread of healthy cities.

Among various environmental factors, 'parks and green spaces' stand out for their significant direct and indirect positive effects on health, highlighting the importance of conducting further research in this area. However, the impact of these spaces varies considerably across different regions, often due to disparities in socioeconomic factors that are tied to local incomes and subsequently to the expansion of infrastructure. This situation has led to a pattern where individuals in wealthier areas generally benefit from superior parks and green environments(Astell-Burt et al., 2014; Bruton & Floyd, 2014; Dai, 2011; Hoffimann et al., 2017; Kihal-Talantikite et al., 2013; Wen et al., 2013). Such disparities are observed worldwide and have given rise to discussions on the equity of access to these crucial green assets from the perspective of Environmental Justice, emphasizing the need for equitable enjoyment of these resources by everyone(Jennings et al., 2012; Kronenberg et al., 2020; Wolch et al., 2014). Beyond parks and green spaces, the discussion has expanded to include 'green infrastructure', which encompasses not only parks as urban planning units but also buffer green spaces, roadside greenery, green spaces within apartment complexes, and facility-associated green spaces(Bowen & Lynch, 2017; Coutts, 2016; Nieuwenhuijsen, 2021). In the post-COVID era, the importance of readily accessible and usable green spaces has been underscored, shifting the focus from quantitative measures like per capita park area to the connectivity, form, and quality of green infrastructure as critical factors(Mell & Whitten, 2021; Uchiyama & Kohsaka, 2020).

Purpose and gap of the Present Study

Until now, research related to green infrastructure and health has often focused on quantitative measures such as quantity, area, and proportion, or has been based on non-specialized health indices(Carthy et al., 2020; Houston, 2014; Zhang et al., 2021). However, there has been significant progress in both quantitative measurements and indicator areas. For example, advancements in GIS technology have enabled detailed accessibility analyses based on network distances to parks and green spaces(Cui et al., 2022; Dipeolu et al., 2021; Long et al., 2023; Ruiz-Apilánez et al., 2023; Şenol et al., 2023). In the realm of health indices, whereas research previously relied on subjective or fragmentary indices such as BMI, stress levels, and neighborhood satisfaction, there has been a shift towards using metrics like physical activity levels and mental health surveys, which are employed in medical journals and by the medical community(Fouad et al., 2023; Islam & Hossain, 2022; Liao & Du, 2022; Liu et al., 2023; Twohig-Bennett & Jones, 2018).

Most research addressing equity has primarily focused on aspects such as the accessibility to parks, green spaces, or green infrastructure, or they were based on rough data on green spaces and aggregated health data, often leading to ecological fallacies(Ko et al., 2019; Lee et al., 2016). Studies that utilized precise health indicators at the individual level and differentiated green infrastructure into detailed categories have been almost non-existent.

South Korea is a prime example of a country that underwent rapid industrialization and swift urban development during the 1970s and 1980s. Particularly notable is that about 50% of the population resides in the metropolitan area, which comprises a mix of established urban areas and newly developed cities. Among these, Seongnam City, which is adjacent to Seoul, serves as an exemplary case study for comparing regional differences due to urban development and expansion. It is uniquely composed of equal parts newly developed city(new town) and established urban area(old town) within a single administrative district. Although there are papers addressing the socioeconomic factors and equity in the distribution and accessibility of parks and green spaces between old town and new town in Seongnam City, these studies fall short of exploring the linkage between these aspects and health(Lim et al., 2009; Shin, 2009). Hence, this research intends to analyze the individual person's accessibility equity of green infrastructure in Seongnam City, differentiated by region and type of green infrastructure. Moreover, it aims to explore the effects of these green infrastructure disparities on health outcomes, employing globally recognized health indices.

Method

Survey

An online survey was conducted to evaluate individual accessibility to green infrastructure. The survey took place from May 12 to May 18, 2023, and garnered a total of 645 responses. The survey was structured into five sections: the first section covered socioeconomic variables, the second section focused on health indices, the third section dealt with the importance and satisfaction levels concerning the neighborhood environment, the fourth section addressed green infrastructure variables, and the fifth and final section was about income.

The health indices will be used as dependent variables, and a literature review was conducted to employ accredited indicators. After comparing and analyzing 14 survey items, including three for physical activity and four for mental health, the physical activity was assessed using the IPAQ-SF (International Physical Activity Questionnaire - Short Form) and mental health was evaluated with the PHQ-9 (Patient Health Questionnaire-9).

The dependent variables for the final ordinal regression analysis included IPAQ, PHQ-9, and green infrastructure satisfaction. For the IPAQ, MET calculation formulas were applied where walking activities were multiplied by 3.3, moderate physical activities by 4.0, and vigorous activities by 8.0 to compute the MET values. Physical activity levels were then categorized into 1 (low), 2 (moderate), and 3 (high) based on their intensity. For the PHQ-9 scores, 0-4 points indicated no depression, 5-9 points low depression, 10-14 points moderate depression, 15-19 points moderately severe depression requiring treatment, and 20 points or above indicated severe depression, all of which were divided into stages from 1 to 5. The green infrastructure satisfaction was directly used as surveyed on a 5-point scale.

Variable setting

Green infrastructure data was refined using GIS and FRAGSTATS to establish variables for the urban environment. Initially, the data underwent a refinement process to discern the detailed impacts of green infrastructure. The available GIS data, comprising solely of national park and green space polygons, did not fully represent all aspects of green infrastructure. To overcome this, a combination of national data, OpenStreetMap (OSM) data, land cover data, and local government-provided park and green space point data was utilized. Additionally, green spaces within apartment complexes were isolated by merging national building complex polygons with apartment address data and applying a clipping method for refinement. The classification process further separated the green spaces into clearly defined public green spaces, and semi-public green spaces such as buffer zones and pathways. Consequently, green infrastructure was divided into three levels: public green spaces, semi-public green spaces, and private green spaces.

The AID-PRIGSHARE toolkit was utilized to derive accessibility indicators for green infrastructure. This toolkit, which is compatible with the QGIS platform, provides a standardized method for analyzing green infrastructure across international park and green space research(Cardinali et al., 2023). Its application enabled the extraction of various indicators, including areas within network buffers ranging from 100m to 1500m, intersect areas, ratios, the shortest access distance (measured in 100m increments), and the diversity of facilities and amenities within parks and green spaces. This research was conducted focusing on areas within a 100~300m radius. The analysis was conducted at the addresses of 645 individual respondents, allowing us to measure individual access to green infrastructure.

FRAGSTATS was used to understand the distribution pattern of green infrastructure. FRAGSTATS is a computer software program developed for quantitatively analyzing landscape structure, patterns, and distribution. It is predominantly used in ecology and geography, particularly for studying changes in land use and cover, green infrastructure, biodiversity, and habitat quality. FRAGSTATS is regarded as an indispensable tool for comprehending spatial data's complexity and analyzing specific areas' ecological characteristics. Researchers employing FRAGSTATS are able to compute various statistics from spatial data, such as satellite imagery or Geographic Information System (GIS) data. These statistics encompass patch numbers, sizes, densities, edge lengths, core areas, fragmentation indices, and diversity indices. Such metrics are instrumental in evaluating habitat fragmentation within a region, habitat connectivity, and the ability to deliver diverse ecosystem services(McGarigal, 1995). In this study, the aim was to determine the accessibility and distribution differences of green infrastructure relative to individual residences. Therefore, a 300m radius around each residence was defined, and the area was clipped to conduct individual analyses using FRAGSTATS. Through this process, six key metrics were extracted from FRAGSTATS: patch cohesion index, patch density, shape index, core area index, edge density, and patch area. These metrics provide a detailed understanding of the spatial configuration and ecological value of green infrastructure in residential areas.

A Space Syntax analysis was conducted to compare the urban spatial structures of new and old towns. Specifically, to analyze pedestrian zone perception and accessibility, lines designated as Trunk and Highway for vehicles only were removed from Open Street Map to construct a pedestrian network. Then, the network within a 5 km radius of the boundary of Seongnam City was extracted to minimize edge effects. The Space Syntax Toolkit in QGIS was used for the analysis. The Network Cleaner function was utilized to simplify unnecessary lines, followed by running Network Segment and the Verify function under Graph Analysis. The settings were changed to angular before executing the Segment function in DepthmapX remote. Finally, values were checked using Attributes Explorer, and data was extracted through Space Syntax analysis using a local radius of 300m. Using this analysis, metrics such as Connectivity, Global Integration, Global NAIN (Normalized Angular Integration), Global NACH (Normalized Angular Choice), Integration, NAIN (Normalized Angular Integration), and NACH (Normalized Angular Choice) were extracted(Hillier et al., 2012).

Result and Discussion

The Mann-Whitney test comparisons of factors such as physical activity (IPAQ), average daily walking time, mental health (PHQ9), quality of life (EQ5D), overall satisfaction with life, and satisfaction with parks and green spaces showed no significant differences between the old and new town areas, with one exception. Satisfaction with parks and green spaces was significantly higher in new town. This difference points to variations in the urban environments regarding parks and green spaces, yet suggests no significant health disparities between the two regions(Figure 1).

T-tests on AID-PRIGSHARE, FRAGSTATS, and Space Syntax metrics were conducted to understand the differences in variables across regions. The results indicated that FRAGSTATS and Space Syntax are analyzed irrespective of green infrastructure accessibility, allowing for comprehensive analysis across all areas. In old town areas, all Space Syntax values were statistically higher compared to new town areas, suggesting that the old town, which started from unplanned development, has higher road connectivity. This implies that the region's initial pattern of development, which began with smaller alley-level developments rather than block-level ones, still influences its current layout. For FRAGSTATS, all values were higher in new town areas compared to old town ones, indicating that the quality of green infrastructure is statistically superior in new town areas. This result can be interpreted as showing that the new town has a significantly better environmental quality in terms of green infrastructure compared to the old town.

However, a problem arose with AID-PRIGSHARE, as the analysis itself would not be feasible if there was no green infrastructure accessible within 300m. This resulted in a discrepancy between the old town and new town areas in terms of calculable individual analysis units. When the analysis was conducted using the 300m criterion, among 335 individuals in the new town and 310 individuals in the old town, the breakdown of individuals and percentages accessing public green spaces, quasi-public green spaces, and green spaces within complexes was as follows: In the new town, 327 individuals (97.61%) had access to the total green spaces, while in the old town, this figure was 237 individuals (76.45%), indicating significantly lower green infrastructure accessibility in the old town compared to the new town. In terms of public green spaces, 281 individuals (83.88%) in the new town had access compared to 173 individuals (55.81%) in the old town, indicating significantly better accessibility in the new town. However, it can be observed that the old town has an advantage in terms of size and area compared to the new town. For semi-public green spaces, there was a significant difference, with 205 individuals (61.19%) in the new town compared to 65 individuals (20.97%) in the old town, although statistically, there was no significant difference between the two areas. As for green spaces within complexes, 296 individuals (88.36%) in the new town and 168 individuals (54.19%) in the old town had access, indicating a similar difference between the two areas as observed with public green spaces. Statistically, the new town had significantly higher accessibility compared to the old town. Finally, regarding diversity metrics, statistically significant higher values were observed in the new town compared to the old town. In summary, while public green spaces and green spaces within complexes showed higher accessibility in the new town compared to the old town, statistically significant differences were observed in terms of area. Public green spaces were more significant in the old town, whereas green spaces within complexes showed significantly larger areas in the new town. Although no significant difference was found in quasi-

The findings highlight distinct distribution patterns and quantitative differences in green infrastructure between old and new town areas, revealing regional variances. To understand the health impacts of this varied green infrastructure, correlation graphs were plotted assessing the relationship between the extent of green infrastructure within a 300-meter radius and various health-dependent variables. The analysis confirmed that the type of green infrastructure affects health outcomes differently. For physical activity, positive correlations were seen in new towns with public and private green spaces, while in old towns, semi-public green spaces were positively associated. This implies that the promotion of physical activity is influenced by the specific nature of green infrastructure within different localities. The pattern for walking time differed from that of physical activity. In new towns, an increase in public and private greenery was equally associated with more walking, whereas in old towns, an increase in semi-public and private green spaces was linked to increased walking time, albeit with a subtler effect than that seen with physical activity. In the case of mental health, higher scores indicating better mental health correlate with increased depression; therefore, the results must be interpreted inversely. In new cities, public and semi-public green spaces showed negative correlations with mental health, whereas private green spaces showed a positive correlation. In contrast, old cities showed a negative correlation with public green spaces and a positive correlation with semi-public green spaces. Regarding the quality of life related to health, in new cities, both public and semi-public green spaces showed negative correlations, while in old cities, public green spaces showed a negative correlation, and semi-public green spaces showed a positive correlation. As for life satisfaction, in new cities, public and semi-public green spaces negatively correlated, but private green spaces showed a positive correlation. In old cities, public green spaces showed a negative correlation, while semi-public green spaces showed a positive correlation. In summary, although not all respondents have access to green infrastructure within 300 meters, among those who do, in new cities, private green spaces, and in old cities, semi-public green spaces show a significant positive correlation with overall health improvement. These findings reveal clear differences in the types of green infrastructure that have positive effects on health in different regions. To determine if these effects are statistically significant, an ordinal logistic regression analysis was conducted using physical activity, mental health, and satisfaction with green infrastructure.

The ordinal logistic regression analysis identified several factors impacting physical activity levels indicated by the IPAQ scores and mental health status as measured by the PHQ-9 scores. Age-wise, individuals aged 15-29 showed significantly lower physical activity levels across all areas (coefficient -0.909, $p<0.001$) and especially in Newtown (coefficient -1.212, $p<0.001$), implying a trend towards lower physical activity among the youth in this area. Gender differences were apparent, with men displaying significantly lower levels of physical activity than women across all areas (coefficient -0.690, $p<0.001$) and in both Newtown (coefficient -0.648, $p=0.012$) and Oldtown (coefficient -0.779, $p=0.002$). Green Infrastructure satisfaction was inversely related to physical activity levels, suggesting that higher satisfaction with G.I. correlates with lower IPAQ scores, though this was only significant at the $p<0.1$ level across all areas ($p=0.053$). This relationship was significant in Newtown (coefficient -0.300, $p=0.068$), but not in Oldtown. Furthermore, 'Core Area within 300m' from Fragstats significantly correlated with physical activity levels across all areas (coefficient -0.029, $p=0.030$), suggesting that larger core green spaces might encourage more physical activity. Regarding G.I. Accessibility, the proximity to green infrastructure within 300m, compared to not having such access, had a significant impact in Oldtown (coefficient -1.057, p=0.037), indicating the potential positive influence of green space accessibility on physical activity.

As for mental health, the younger population in Newtown is at a heightened risk for depression, as indicated by significant relationships between the 15-29 age group and higher PHQ-9 scores (coefficient 1.027, p=0.005). Men demonstrated significantly lower PHQ-9 scores than women in all areas (coefficient -0.727, p<0.001) and Newtown (coefficient -1.217, p<0.001), pointing to a potentially lower risk of depression. Life Satisfaction was strongly negatively associated with PHQ-9 scores across all areas (coefficient -0.683, p<0.001), denoting that higher life satisfaction is linked with better mental health. Access to Public G.I. within 300m BSA was positively related to PHQ-9 scores in all areas (coefficient 3.013E-05, p=0.035) and somewhat in Oldtown (coefficient 3.084E-05, p=0.082), whereas Semi-Public G.I. showed a negative effect in Oldtown (coefficient 9.015E-05, p=0.029). The 'Core Area within 300m' from Fragstats also exhibited a minor yet significant influence on PHQ-9 scores across all areas (coefficient -0.040, p=0.026).

The results from the ordinal logistic regression analysis for Green Infrastructure (G.I.) Satisfaction reveal significant associations with various demographic and spatial variables across different locations. Starting with the highest level of G.I. satisfaction (G.I. Satisfaction 5), individuals in this category are significantly more satisfied compared to the lowest satisfaction group across all areas (coefficient 4.649, p<0.001), in Newtown (coefficient 3.453, p=0.004), and in Oldtown (coefficient 3.777, p<0.001). This positive trend is also observed for G.I. Satisfaction 4 and 3, indicating that higher satisfaction with green infrastructure is consistently linked with positive outcomes. However, when we look at G.I. Satisfaction 1 (the lowest), there's a significant negative relationship in Oldtown (coefficient -1.955, p=0.011), showing that the least satisfied individuals report worse outcomes than the reference group. Regarding location, living in Newtown is associated with higher satisfaction compared to Oldtown (coefficient 0.801, p=0.002), suggesting location-specific differences in the perception and utility of green infrastructure. Age also plays a role, with the group aged 30-39 years showing a slight but not significant negative association with G.I. satisfaction across all areas (coefficient -0.330, p=0.086) and a significant negative relationship in Newtown (coefficient -0.561, p=0.043). Gender does not seem to have a strong impact on G.I. satisfaction with inconsistent and non-significant coefficients across the locations. Income level shows a negative but non-significant trend for medium income across all areas and specific locations when compared to high income, suggesting that income may not be a strong predictor of G.I. satisfaction in this analysis. Life Satisfaction displays a very strong and significant positive relationship with G.I. satisfaction across all areas (coefficient 0.198, p<0.001), reinforcing the notion that satisfaction with life in general is also reflected in the satisfaction with green infrastructure. When it comes to spatial factors, Local Integration within a 300m Buffer shows a negative association with G.I. satisfaction in the overall area (coefficient -0.011, p=0.008) and a significant negative impact in Oldtown (coefficient -0.014, p=0.006). The type of G.I. within 300m of the residential area also matters, with Public G.I. being positively associated with G.I. satisfaction across all areas (coefficient 2.677E-05, p=0.040) and in Oldtown (coefficient 4.366E-05, p=0.008). However, Semi-Public G.I. shows a negative relationship in Newtown (coefficient -8.172E-05, p=0.017), suggesting different types of G.I. might affect satisfaction levels differently. Fragstats analysis indicates that Core Area within 300m is positively associated with G.I. satisfaction across all areas (coefficient 0.044, p=0.002) and in both Newtown (coefficient 0.039, p=0.055) and Oldtown (coefficient 0.049, p=0.039). Lastly, accessibility to G.I. shows contrasting results with a significant negative impact in Newtown (coefficient -3.066, p=0.008) for G.I. within 300m, while in Oldtown, the presence of G.I. within 300m shows a significant positive association (coefficient 1.208, p=0.012). This analysis underscores the complex relationship between demographic factors, satisfaction with life, and the perceived value of green infrastructure, demonstrating significant variation across different population segments and geographical areas(Table 1).

The connection between the availability and quality of G.I. and various health outcomes is complex and multi-dimensional. Previous studies corroborate our findings that younger individuals exhibit lower physical activity levels, which could be attributed to sedentary lifestyles and increased indoor leisure activities that technology affords (Lou, 2014). This is consistent with our results showing reduced physical activity among the 15-29 age group, particularly in Newtown. Gender disparities in physical activity, where men exhibited lower activity levels than women, challenge the conventional narrative. Literature often suggests that women face more barriers to physical activity due to safety concerns and cultural expectations (Giles-Corti & Donovan, 2002). However, our findings could reflect a shift in gender roles or the success of targeted initiatives encouraging women's participation in physical activity. The negative correlation between G.I. satisfaction and IPAQ scores, albeit significant at a p<0.1 level, suggests that higher satisfaction with green spaces doesn't necessarily translate to increased physical activity. This could imply that while people appreciate the aesthetic or recreational value of green spaces, they may not use these spaces for physical activity (Kaczynski & Henderson, 2007). Semi-Public G.I. within 300m BSA's negative effect on mental health in Oldtown may reflect a misalignment between the type of G.I. available and the community's needs. As per (Wolch et al., 2014), semi-public spaces may not offer the same mental health benefits as fully public green spaces due to perceived exclusivity or limited accessibility.

Implications and policy suggestions

The demographic and regional differences observed suggest tailored approaches to urban planning. Policies should prioritize the creation of multi-functional green spaces that cater to the diverse needs of various age groups and genders. For instance, implementing urban parks with features attractive to youth, like sports facilities or community gardens, may encourage physical activity among younger demographics. Moreover, the type of G.I. is as important as its availability. Fully public green spaces should be prioritized in urban development for their broader accessibility and potential mental health benefits.

Conclusion

The study presents compelling evidence of the importance of green infrastructure in promoting physical and mental health in urban populations. While individual preferences and satisfaction play a role, demographic factors and the types of G.I. available also significantly impact health outcomes. Urban planners and policymakers must consider these factors to create equitable, health-promoting urban environments. It's critical to continue this line of research, expanding the scope to include longitudinal studies that can account for changes over time, and experimental designs that can more conclusively establish causality. As our urban landscapes evolve, so too must our strategies for creating healthy, sustainable communities where all citizens can thrive.

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Figure 1. Mann-Whitney results for the dependent variable(IPAQ, PHQ9, EQ5D, Satisfaction)

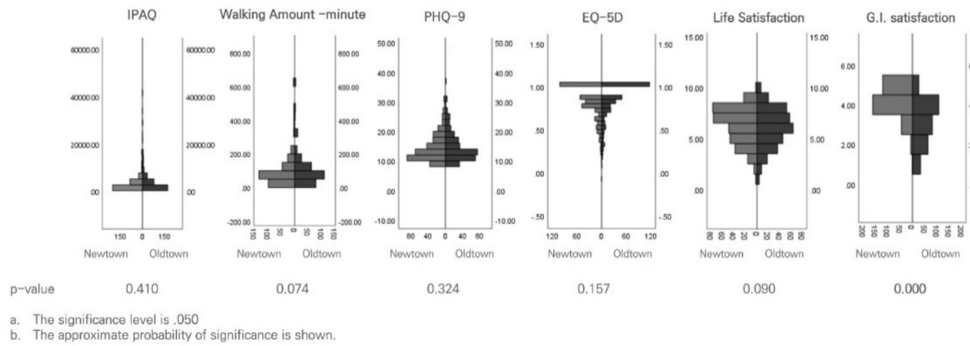

Figure 2. Graph of green infrastructure types and health metrics correlation by region

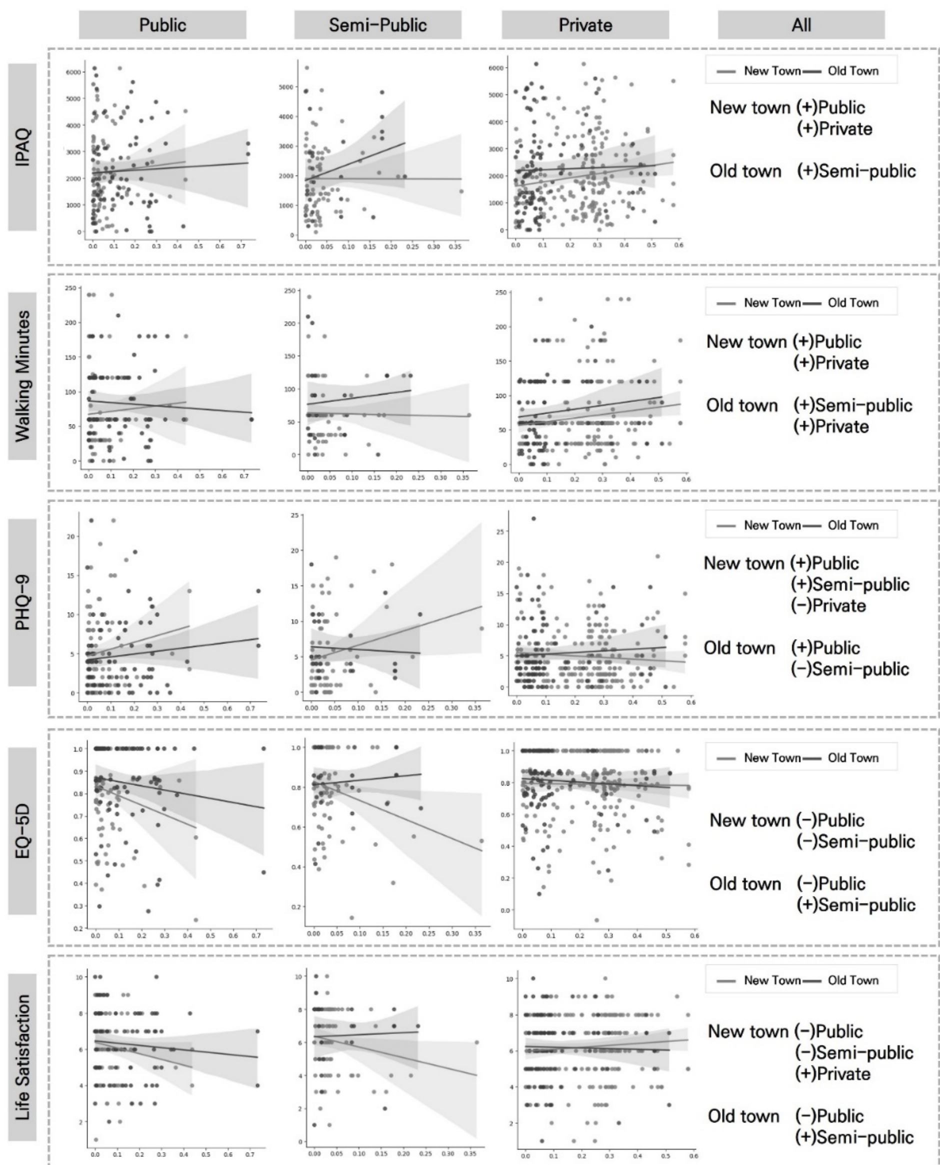

Table 1. Results of ordinal regression analysis of IPAQ, PHQ9, G.I. Satisfaction

IPAQ										
Variables		All area			Newtown			Oldtown		
		Coeff.	Wald	P-value	Coeff.	Wald	P-value	Coeff.	Wald	P-value
IPAQ	High level PA	**Reference**			**Reference**			**Reference**		
	Moderate level PA	-0.914	2.311	0.128	-2.054	2.667	0.102	-0.211	0.064	0.800
	Low level PA	-3.088	25.192	0.000	-4.227	10.932	0.001	-2.486	8.567	0.003
Location	Oldtown	**Reference**								
	Newtown	0.233	0.858	0.354						
Age	Age 40-64 years	**Reference**			**Reference**			**Reference**		
	Age 30-39 years	-0.469	5.908	0.015	-0.479	3.202	0.074	-0.481	2.794	0.095
	Age 15-29 years	-0.909	16.491	0.000	-1.212	13.881	0.000	-0.639	3.918	0.048
Gender	Gender(woman = 2)	**Reference**			**Reference**			**Reference**		
	Gender(man=1)	-0.690	15.066	0.000	-0.648	6.285	0.012	-0.779	9.206	0.002
Income	High income	**Reference**			**Reference**			**Reference**		
	Medium income	0.152	0.435	0.510	0.311	1.152	0.283	0.048	0.014	0.904
	Low income	-0.107	0.189	0.664	-0.217	0.430	0.512	0.095	0.056	0.813
Satisfaction	Life Satisfaction	-0.035	0.631	0.427	-0.051	0.603	0.437	-0.003	0.002	0.963
	G.I. Satisfaction	-0.185	3.750	0.053	-0.300	3.320	0.068	-0.111	0.812	0.367
Space Syntax	Local Intergation within 300m Buffer	-0.002	0.119	0.730	-0.007	0.179	0.673	0.001	0.029	0.866
G.I. Type	Public G.I. within 300m BSA	-4.790E-06	0.137	0.711	-4.057E-05	2.659	0.103	6.997E-06	0.182	0.669
	Semi-Public G.I. within 300m BSA	-1.370E-05	0.300	0.584	4.618E-06	0.018	0.893	-3.739E-05	0.836	0.361
	Private G.I. within 300m BSA	1.312E-05	1.127	0.288	1.389E-05	0.776	0.378	2.584E-05	1.013	0.314
Fragstats	Core Area within 300m	-0.029	4.682	0.030	-0.038	4.381	0.036	-0.011	0.208	0.648
	Edge Density within 300m	-0.001	0.667	0.414	-0.002	0.896	0.344	-0.001	0.151	0.697
G.I. Accessibility	G.I. without 300m	**Reference**			**Reference**			**Reference**		
	G.I. within 300m	-0.550	1.536	0.215	0.236	0.042	0.838	-1.057	4.339	0.037
	G.I. within 200m	0.206	0.316	0.574	0.269	0.088	0.767	0.086	0.041	0.839
	G.I. within 100m	-0.124	0.148	0.700	0.055	0.005	0.945	-0.334	0.681	0.409
PHQ-9										
Variables		All area			Newtown			Oldtown		
		Coeff.	Wald	P-value	Coeff.	Wald	P-value	Coeff.	Wald	P-value
PHQ-9	PHQ9 5 (severe (need treatment)) 20-27	**Reference**			**Reference**			**Reference**		
	PHQ9 4 (moderate (severe)) 15-19	0.077	0.010	0.920	-1.224	0.547	0.459	0.546	0.283	0.595
	PHQ9 3 (moderate) 10-14	-1.803	6.946	0.008	-3.577	5.499	0.019	-1.055	1.264	0.261
	PHQ9 2 (mild) 5-9	-3.268	22.771	0.000	-5.331	12.118	0.000	-2.295	6.006	0.014
	PHQ9 1 (Not) 0-4	-5.048	50.858	0.000	-7.209	21.255	0.000	-4.032	17.561	0.000
Location	Oldtown	**Reference**								
	Newtown	0.329	1.318	0.251						
Age	Age 40-64 years	**Reference**			**Reference**			**Reference**		
	Age 30-39 years	0.402	3.367	0.067	0.614	3.820	0.051	0.236	0.555	0.456
	Age 15-29 years	0.708	7.959	0.005	1.027	7.833	0.005	0.419	1.356	0.244
Gender	Gender(woman = 2)	**Reference**			**Reference**			**Reference**		
	Gender(man=1)	-0.727	12.214	0.000	-1.217	13.353	0.000	-0.416	2.167	0.141
Income	High income	**Reference**			**Reference**			**Reference**		
	Medium income	0.059	0.048	0.827	-0.008	0.000	0.983	0.075	0.025	0.874
	Low income	-0.032	0.013	0.910	-0.127	0.108	0.742	-0.009	0.000	0.984
Satisfaction	Life Satisfaction	-0.683	141.733	0.000	-0.822	83.179	0.000	-0.582	56.733	0.000
	G.I. Satisfaction	-0.149	1.961	0.161	-0.315	2.977	0.084	-0.074	0.288	0.591
Space Syntax	Local Intergation within 300m Buffer	-0.009	3.277	0.070	-0.003	0.025	0.874	-0.006	1.001	0.317
G.I. Type	Public G.I. within 300m BSA	3.013E-05	4.451	0.035	2.777E-05	1.000	0.317	3.084E-05	3.018	0.082
	Semi-Public G.I. within 300m BSA	4.084E-05	2.420	0.120	3.197E-06	0.008	0.930	9.015E-05	4.750	0.029
	Private G.I. within 300m BSA	4.943E-06	0.126	0.722	6.168E-06	0.115	0.734	1.254E-05	0.205	0.651
Fragstats	Core Area within 300m	-0.040	4.971	0.026	-0.040	2.559	0.110	-0.045	2.434	0.119

	Edge Density within 300m	-0.002	0.812	0.367	-0.003	1.019	0.313	-0.001	0.026	0.873
G.I. Accessibility	G.I. without 300m	**Reference**			**Reference**			**Reference**		
	G.I. within 300m	-1.025	3.434	0.064	-2.108	1.836	0.175	-0.848	1.960	0.161
	G.I. within 200m	-0.212	0.267	0.605	0.109	0.010	0.921	-0.351	0.573	0.449
	G.I. within 100m	-0.359	1.007	0.316	-0.441	0.209	0.647	-0.577	1.742	0.187
G.I. Satisfaction										
Variables		**All area**			**Newtown**			**Oldtown**		
		Coeff.	Wald	P-value	Coeff.	Wald	P-value	Coeff.	Wald	P-value
G.I. Satisfaction	G.I. Satisfaction 5 (Highest)	**Reference**			**Reference**			**Reference**		
	G.I. Satisfaction 4	4.649	63.056	0.000	3.453	8.370	0.004	3.777	23.075	0.000
	G.I. Satisfaction 3	2.103	14.120	0.000	0.729	0.384	0.536	1.238	2.689	0.101
	G.I. Satisfaction 2	0.477	0.745	0.388	-1.445	1.416	0.234	-0.285	0.144	0.704
	G.I. Satisfaction 1 (Lowest)	-1.183	4.268	0.039	-3.589	5.510	0.019	-1.955	6.547	0.011
Location	Oldtown	**Reference**								
	Newtown	0.801	10.048	0.002						
Age	Age 40-64 years	**Reference**			**Reference**			**Reference**		
	Age 30-39 years	-0.330	2.944	0.086	-0.561	4.111	0.043	0.089	0.103	0.748
	Age 15-29 years	-0.227	1.063	0.303	-0.721	4.858	0.028	0.250	0.644	0.422
Gender	Gender(woman = 2)	**Reference**			**Reference**			**Reference**		
	Gender(man=1)	0.149	0.715	0.398	-0.194	0.540	0.463	0.409	2.780	0.095
Income	High income	**Reference**			**Reference**			**Reference**		
	Medium income	-0.279	1.430	0.232	-0.192	0.408	0.523	-0.636	2.574	0.109
	Low income	-0.290	1.377	0.241	-0.311	0.814	0.367	-0.542	1.893	0.169
Satisfaction	Life Satisfaction	0.198	20.089	0.000	0.317	22.095	0.000	0.079	1.675	0.196
Space Syntax	Local Intergation within 300m Buffer	-0.011	6.950	0.008	0.011	0.497	0.481	-0.014	7.572	0.006
G.I. Type	Public G.I. within 300m BSA	2.677E-05	4.220	0.040	3.894E-05	2.283	0.131	4.366E-05	7.077	0.008
	Semi-Public G.I. within 300m BSA	-4.469E-05	3.268	0.071	-8.172E-05	5.671	0.017	1.781E-05	0.196	0.658
	Private G.I. within 300m BSA	1.800E-05	2.036	0.154	1.190E-05	0.525	0.469	3.424E-05	1.798	0.180
Fragstats	Core Area within 300m	0.044	9.161	0.002	0.039	3.676	0.055	0.049	4.239	0.039
	Edge Density within 300m	0.005	8.765	0.003	0.007	6.944	0.008	0.000	0.002	0.962
G.I. Accessibility	G.I. without 300m	**Reference**			**Reference**			**Reference**		
	G.I. within 300m	0.553	1.646	0.200	-3.066	6.995	0.008	1.208	6.325	0.012
	G.I. within 200m	-0.064	0.032	0.858	-1.355	2.093	0.148	0.079	0.038	0.845
	G.I. within 100m	0.771	5.993	0.014	-0.973	1.418	0.234	1.135	8.467	0.004