How Is the Neighborhood Environment Related to the Health of Seniors Living in Hong Kong, Singapore, and Tokyo? Some Insights for Promoting Aging in Place

Becky P. Y. Loo , Winnie W. Y. Lam, Rathi Mahendran & Keiko Katagiri

How Is the Neighborhood Environment Related to the Health of Seniors Living in Hong Kong, Singapore, and Tokyo? Some Insights for Promoting Aging in Place

Becky P. Y. Loo [ID],* Winnie W. Y. Lam,* Rathi Mahendran,[†] and Keiko Katagiri[‡]

*Department of Geography, The University of Hong Kong
[†]Department of Psychological Medicine, Yong Loo Lin School of Medicine, National University of Singapore
[‡]Graduate School of Human Development and Environment, Kobe University

Aging in place can be a challenge for seniors living in cities, where the infrastructure and associated services are typically designed for the working population to enhance efficiency and productivity. Through surveying community-dwelling seniors, we ask these research questions: How is the neighborhood environment related to the physical and mental health of seniors living in Hong Kong, Singapore, and Tokyo? How can we make cities more age-friendly to encourage aging in place? To answer these research questions, both observational and questionnaire surveys are used. Characteristics of the local neighborhood are captured by individual-based and general local characteristics. Multilevel analysis is used to disentangle the effects of factors operating at different spatial scales. A total of 687 seniors aged sixty-five and older living in Hong Kong, Singapore, and Tokyo in eleven residential neighborhood districts were recruited through local senior community centers. Based on the final models, 17.53 percent and 8.24 percent of the variance in the physical and mental health scores is across general neighborhoods, respectively, and the remaining is at the individual level, including individual-based neighborhood factors. Biological factors are not the most important. Instead, having a normal range of weight and the proper use of a walking aid can allow seniors, even of the oldest-old group of eighty-five and older, to be more active. Policy-wise, neighborhood factors should be carefully planned to promote seniors' health directly through enhancing walkability and fostering supportive peer groups and indirectly through encouraging a more active lifestyle. Promoting a walkable urban environment should be a priority area for supporting aging in place in cities. *Key Words: aging in place, health, multilevel analysis, neighborhood, urban environment.*

由于城市中的基础建设和相关服务主要是为劳动人口增加效率与生产力而设计, 因此在地安养对居住在城市中的年长者而言可能是个挑战。透过调查居住于社区中的年长者, 我们提出以下研究问题·邻里环境如何关乎居住于香港、新加坡和东京的年长者的身体与心理健康··我们如何能够让城市对年龄更为友善, 以鼓励在地安养··为了回答上述研究问题, 我们同时使用观察与问卷调查。我们透过根据个人的以及普遍的在地特徵, 捕捉地方邻里的特徵。我们运用多重层级分析来拆解在不同空间尺度上运作的各因素之效应。我们透过地方老人社区中心, 徵召了总共六百八十七位年龄在六十五岁以上, 并居住于香港、新加坡与东京十一座住宅邻里社区中的年长者。根据最终的模型, 在生理和心理健康的分数中, 分别有百分之十七点五三与百分之八点二四之变异数来自普遍的邻里, 其馀的则位于个人层级, 包含根据个人的邻里因素。生物因素并非最为重要的。反之, 拥有正常的体重范围, 并适当使用步行辅助器, 能够让年长者更为活跃, 即便是最高龄的八十五岁以上之群组。政策方面, 邻里因素应谨慎规划, 并直接透过增加可步行性和培养支持的同柴团体, 以及间接鼓励更为活跃的生活方式来促进年长者的健康。提倡可步行的城市环境, 应该是支持年长者在城市中在地安养的优先面向。 关键词: 在地安养, 健康, 多重层级分析, 邻里, 城市环境。

Envejecer en lugar puede ser un reto para los adultos mayores que viven en las ciudades, donde la infraestructura y servicios asociados típicamente se diseñan para la población trabajadora buscando fortalecer la eficiencia y la productividad. Mediante una encuesta con adultos mayores residentes en comunidad, formulamos las siguientes preguntas de investigación: ¿De qué manera se relaciona el entorno del vecindario con la salud física y mental de los adultos mayores que viven en Hong Kong, Singapur y Tokio? ¿Cómo podemos volver las ciudades amistosas con la mayor edad para estimular el envejecer en lugar? Para contestar estos interrogantes se utilizaron tanto

técnicas de observación como encuestas de cuestionario. Las características del vecindario local son capturadas por características basadas en el individuo y a través de las características generales de la localidad. El análisis a nivel múltiple se usó para desenredar los efectos de factores que operan a diferentes escalas espaciales. Un total de 687 adultos mayores con edades de sesenta y cinco años o más residentes en Hong Kong, Singapur y Tokio, en once distritos residenciales de barrio, fueron seleccionados a través de centros comunitarios locales de ancianos. Con base en los modelos finales, el 17.53 y 8.24 por ciento de la varianza en los puntajes físicos y mentales se da a través de los vecindarios generales, respectivamente, y el resto es a nivel individual, incluyendo factores de vecindario con base individual. Los factores biológicos no son los más importantes. En vez de eso, con una gama normal de peso y el uso apropiado de ayuda para caminar se puede permitir a los adultos mayores, incluso los del grupo más viejo entre los viejos de ochenta y cinco o más años de edad, ser más activos. Para los efectos de políticas, los factores barriales deben ser cuidadosamente planificados para promover la salud de los adultos mayores directamente fortaleciendo la capacidad de caminata y estimulando la constitución de grupos de apoyo entre los compañeros, e indirectamente por medio del estímulo hacia un modo de vida más activo. El promover un entorno urbano caminable debe ser un área prioritaria de apoyo al envejecimiento en lugar en las ciudades. *Palabras clave: envejecimiento en lugar, salud, análisis a nivel múltiple, vecindario, entorno urbano.*

Many key challenges of humankind in the twenty-first century are directly or indirectly related to cities. With higher levels of urbanization, cities are going to be the homes of many more people. Since 2005, the share of the world population living in cities has surpassed that in rural areas (United Nations 2014a). By 2050, it is projected that about 85 percent of the world's population will be living in cities (United Nations 2014b). Yet, cities, as areas of high concentrations of people and activities, are characterized by a fast living pace, high cost of living, congestion, air pollution, traffic congestion, and mental stress, which contrast strikingly with the typical image of peaceful retirement of people in late life. The seminal paper of Laws (1993) in the *Annals of the American Association of Geographers* illustrated the ways in which the urban built environment can be ageist, just as it was sexist (Freidan 1963) and racist (Jackson 1985), by making children and elderly people unwelcome in cities that emphasize efficiency and productivity. More recently, empirical evidence suggests that many more seniors are living in cities, including the largest metropolitan cities. Furthermore, many seniors prefer to live in cities even when given a choice of relocating to "slower" or "quieter" small towns. For instance, since the 1980s, the South Korean government had been anticipating older people to move from urban to rural areas on retirement; this was viewed as a potential driving force for spurring economic growth of rural areas. Large-scale government plans were made to provide adequate health services and housing in rural areas for older people (J. H. Kim and Han 2014). There has been a reverse trend, however, for older people to relocate to or to remain in high-density urban areas with easy access to health services and living amenities over the past decade (J. H. Kim and Han 2014).

Aging in place is the concept of encouraging and supporting older people to live in their familiar neighborhood environment and at home rather than to move to special care facilities (Cabinet Office of Japan 2007). As aging in place gets wider support from the society, cities are likely to be the homes of more seniors. Baby Boomers who were born and brought up in cities are likely to continue living there. In addition, many rural migrants relocated to metropolitan areas during their most productive years and are also likely to stay, as they have spent their most important years of life there. The desire to live near grown-up children and grandchildren also helps to explain the preference of many older people not to leave the cities on retirement. With the Baby Boomers (born soon after World War II [1939–1945]) turning sixty-five years old, the scale and nature of the challenges of aging-in-place have undergone important changes. For instance, there were more than 800 million Baby Boomers in Japan. Many of them were born in rural areas and moved to cities to attain higher education and to get better jobs. Although Japanese rural local governments expected them to go back to their hometowns, many of them were not willing to return and preferred to stay in the cities (Cabinet Office of Japan 2007). Against this background, there is an urgent need to make the urban environment more age-friendly, as the aging trend accelerates worldwide. Moreover, there is a need to better understand the relationship between the urban neighborhood environment and the health of older people living in metropolitan areas.

The Asian Context

Looking back to the 1980s and 1990s, aging was often discussed in developed or high-income

economies. Notably, Preusser et al. (1998) conducted a study among thirty-five industrialized economies in Western Europe, North America, Japan, and Australia and warned that the share of seniors over sixty-five years old already surpassed 13 percent in 2000 and was projected to increase to 22 percent by 2030 and 27 percent by 2050. Nowadays, aging is recognized as a global problem. According to the United Nations' *World Population Aging Report 2015* (United Nations 2015), the share of seniors over sixty years old is expected to rise from 12.5 percent in 2015 to around 17 percent in 2030. It is further projected that in 2050, the proportion of the older population will reach 20 percent. A powerful force driving these trends is the increase in life expectancy of the global population over the last few decades. From 1990 to 2015, the life expectancy of both men and women increased by six years. Combining the statistics for the two sexes, the global population's life expectancy has reached 70.5 years. Beyond the global figures, wide regional differences remained. The life expectancy was generally lowest in Africa (59.5 years) and highest (79.2 years) in the Americas, Europe, and Western Pacific in 2015. Yet, the upward trend of life expectancy was noticeable in all World Health Organization (WHO) regions.

Within Asia, the geographical diversity is striking. Figure 1 shows the expected age profiles of selected Asian economies by 2025. Whereas the population is still relatively young in Malaysia, Indonesia, Vietnam, the Philippines, Burma, Cambodia, and Laos, aging is clearly a pressing problem in Japan, Hong Kong, and Singapore, with 7 to 15 percent of the population expected to be seventy-five years or older by 2025. Within Japan, the largest conurbation of Tokyo had a population of 13.48 million (10.6 percent of the whole country) in 2015. The Tokyo district is large (2,122 km^2) and the percentage of people older than sixty-five reached 23 percent in 2015. That figure is projected to rise to 28.9 percent in 2035 (Phillips 2002). In Hong Kong, the geographical context is worth mentioning. It is a small city of 1,105 km^2 but with a population of 7.32 million (Census and Statistics Department 2012). Furthermore, most of the population live on only 30 percent of the land and a large part of the city is reserved as a national park (Planning Department 2014). With very low birth rates for nearly three decades (from 1980–2010), the share of seniors age sixty-five or above reached 13 percent in 2013, and the figure is expected to increase to nearly 27 percent by 2033. A recent study of the government further projects that by 2041, there will be one senior sixty-five years old or older for every three persons in Hong Kong (Government of the Hong Kong Special Administrative Region 2013). Similarly, Singapore is small in territorial extent. It is a nation state with only 732.3 km^2 and a population of 5.47 million (Department of Statistics Singapore 2015). The status of the city as a melting pot with a diversified population with different races (74 percent Chinese, 13 percent Malays, 9.1 percent Indians, and 3.3 percent others) and religions (33.9 percent Buddhist, 14.3 percent Muslim, 11.3 percent Taoist, 7.1 percent Catholic, 5.2 percent Hindu, and 16.4 percent with no religion) requires any social policy, including the senior policy, to be culturally sensitive (IndexMundi 2015). By 2014, the share of the resident population who were over age sixty-five years was 11 percent. According to the latest report of Japan's Ministry of Health, Labor and Welfare in July 2016, Hong Kong's women and men enjoyed the longest life expectancy in the world, followed by Japanese women and Icelandic and Swiss men (Lee and Cheah 2016). Clearly, the aging population is a key challenge for the governments and academics in these three major metropolitan areas. The fact that these three cities are all in the high-income country category of the World Bank (2015) with the ability to take care of their aging population makes
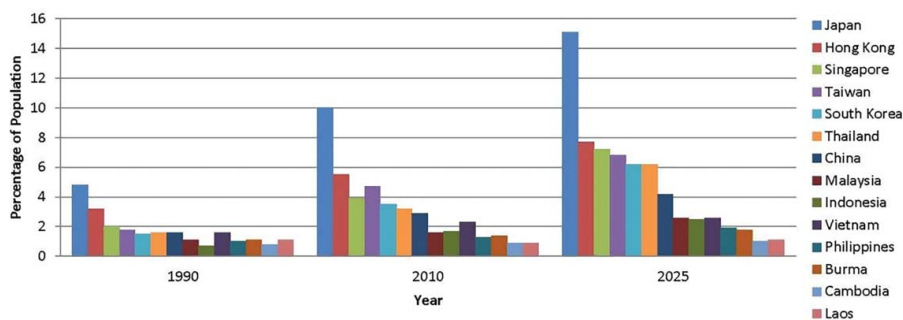

Figure 1. Age profiles of selected Asian economies, 2025. (Color figure available online.)

them excellent case studies for identifying potentially good practices from which other emerging Asian countries can learn. Hence, this article has chosen these three cities for analysis.

Linking People's Activities, Health, and Neighborhood Environment

Although aging is a pressing problem worldwide, aging for an individual is usually a gradual process. As one gets older, different personal challenges arise and there are changing requirements for the living environment. If one thinks about the movements of seniors in society, there are two major areas of concern: mobility and safety. The mobility expectations of the older population keep evolving and diversifying, which needs to be elicited, identified, and acknowledged (Schwanen and Páez 2010). These are the mobility questions: How active are the seniors in society (Hirvensalo, Rantanen, and Heikkinen 2000)? Where do they go (Alsnih and Hensher 2003)? How do they move around (S. Kim and Ulfarsson 2004)? What are the associated mobility problems (Rosenbloom 2003)? How can their movements be better supported to encourage them to engage actively in various activities (Lui et al. 2009)? To illustrate, one of the factors that is most relevant to the older population is health care facilities. For seniors with chronic diseases, making medical trips to these facilities is essential (Coughlin 2001). Barriers and difficulties in getting to these facilities can easily become a source of stress and, in some cases, even stop them from making these regular visits to get needed medical attention, which can give rise to negative health consequences (Syed, Gerber, and Sharp 2013). In Hong Kong, nearly half of all medical trips made by seniors were made by public transport, mostly buses and taxis; another one fifth were made by walking (Loo and Lam 2012). Hence, improving public transport accessibility and the walking environment near medical facilities is crucial for aging in place.

Equally important are concerns about traffic safety. The elderly are highly vulnerable to road traffic injury. A report from the WHO (2013) highlighted that with the ever-increasing aging population, the risk for those in the elderly group of being killed or seriously injured in traffic has become a significant challenge. The following are some key questions: How serious are the traffic risks for senior road users (Ameratunga, Hijar, and Norton 2006)? Where are the high-risk locations

for them (Mayhew, Simpson, and Ferguson 2006)? When are their risks particularly high (Lam, Yao, and Loo 2014)? Who are the most vulnerable subgroups (Zhang et al. 2000)? How should traffic safety for seniors be improved (Mori and Mizohata 1995)? Using local hospital data in Hong Kong, Loo and Tsui (2009) found that a senior pedestrian hit by a vehicle was about 3.6 times more likely to die than a younger adult between fifteen and sixty-four years old. To properly understand the risk to senior pedestrians, it is important to analyze not only detailed traffic collision patterns but also the spatiotemporal patterns of senior pedestrian movements to measure exposure appropriately (Yao, Loo, and Lam 2015).

The promotion of mobility and improvement of road safety facilitate an active way of life and are means to safeguard and enhance the quality of life of seniors. In this article, *quality of life* is taken to mean the experience or perception of individuals of how well one lives (Oleson 1990). With the clear goal of enhancing the quality of life, people can be seen as nested within and moving around their living environment at different spatial scales. As individuals, each of us possesses a set of physical features, values, and thoughts. Much time is spent within the microscale living environment of one's home. Beyond home, there is the mesoscale living environment of the local neighborhood or community, roughly taken to be about a ten-minute walk or 500 m around one's home. Finally, there is also the macrolevel living environment, which could encompass the city, region, country, and beyond, depending on one's actual level of mobility and lifestyle (Figure 2). It is with this geographical framework of a multiscale environment that we developed this study.

Conceptually, each scale of the living environment has its own geographical characteristics and exerts both direct and indirect influences within and across other scales. Focusing on the seniors and their quality of life, much research has shown that improvements in the home environment using age-friendly home designs, particularly for bathrooms, or the use of simple mechanics to lift heavy loads can greatly support older people in living independently at home and enhance their quality of life (Graafmans 1998). Healthy seniors do not just stay at home, however. Previous studies on the mobility of the elderly found that the daily trip rates of older people nowadays are higher than they were twenty years ago, and out-of-home activities have also become more common (Hjorthol, Levin, and Sirén 2010; Burton, Mitchell, and Stride 2011;
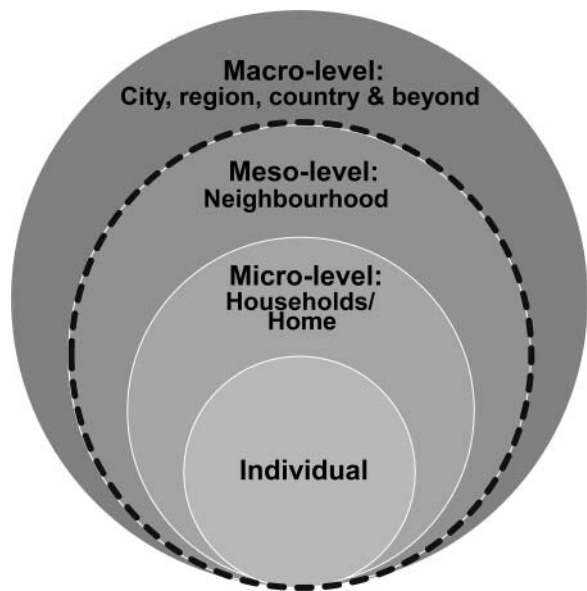
Figure 2. The multiscale environment geographical framework.

Mollenkopf, Hieber, and Wahl 2011). Although they tend to have a more restricted activity space with their reduced physical strength, they tend to move around mostly in the proximity of their residential locations. *Activity space* is a term that describes locations and routes a person has direct contact with on a regular basis (Sherman et al. 2005). In relation, Wiles et al. (2009) found that older people tend to spend most of their time near their homes. In this study, we raised three specific research questions:

1. How healthy are the community-dwelling seniors in Hong Kong, Singapore, and Tokyo?
2. To what extent are neighborhood factors significant in understanding the health of seniors?
3. What are the key facilitators and barriers for enhancing the health of seniors?

Method

Surveys in the Three Cities: Empirical Constraints and Limitations

In trying to answer these research questions, we need to approach community-dwelling seniors in Hong Kong, Singapore, and Tokyo. The best way to reach the potential target population is to approach them in the local communities in which they live. The research team traveled and reached out to different local communities through the support of local senior community centers. The research involves

minimal risk to the survey participants and obtained the ethical approvals in all three cities.

In Hong Kong, a comprehensive list of 248 local senior community centers was obtained from the Social Welfare Department. It represents the best sampling frame available. The research team randomly approached the centers. Initial site visits were conducted to ensure that the venue was large enough and there were at least fifty members interested. The Hong Kong samples of 242 seniors came from four centers in the three main regions of the city—Kowloon (Hung Hom and Tai Kok Tsui), the New Territories (Tai Po), and Hong Kong Island (Sai Ying Pun). In Singapore, the study was done at the Training and Research Academy (TaRA), an established community-based research center for the Department of Psychological Medicine of the National University of Singapore. It is in Jurong West district, which has a senior population (sixty-five years or older) of 21,120. The neighborhood is characterized by mainly public housing (Housing & Development Board 2016). In total, 247 seniors were recruited in Singapore. In Tokyo, there were 198 seniors from a community senior center located in Nerima Ward, a residential area in the suburbs of Tokyo. Nerima Ward has a senior population of 152,444 and four local senior community centers. A noteworthy point is that Japanese senior centers do not encourage users to go there by car, so most local users go there by public transport, walking, or both. In our study, some seniors came to the center on foot from more than 5 km away. In comparison with both Singapore and Tokyo, the senior community centers in Hong Kong are much smaller, in terms of both physical size and membership size. Hence, more senior community centers were selected.

Given that questionnaires are the major survey instruments used to obtain the primary data, including perceptual and attitudinal data, we excluded seniors who were found to have serious and moderate cognitive impairments (a Mini-Mental State Examination [MMSE] score below twenty-one; Loo and Tsui 2016). Advice was given to these individuals by the medical staff or psychologists, who conducted the MMSE test in the field. Given that community senior centers represent the only feasible way (to the research team) of approaching community-dwelling seniors, as local residents' registers are not available, the samples were not recruited based on random sampling. The research team recognizes this limitation with the aim of providing the first systematic study on this important topic in the three major metropolitan areas in Asia.

Dependent Variables: Health Scores

Health is a key element in affecting quality of life and life satisfaction (Smith, Avis, and Assmann 1999; Kwan 2013). Health-related quality of life is usually defined as the "physical, psychological, and social domains of health, seen as distinct areas that are influenced by a person's experiences, beliefs, expectations, and perceptions" (Testa and Simonson 1996, 835). Because life satisfaction is measured as an aggregate assessment of an individual's satisfaction in various life domains (Cummins 1996), being healthy is not a sufficient condition for good quality of life. Yet, ill health is most likely to contribute to poor quality of life. Also, for health, one needs to consider both the physical component—generally encompassing physical functions, role limitations due to physical health problems, bodily pain, and general health—and the mental component—covering mental health, role limitations due to emotional problems, social functioning, and vitality.

In this study, the key health-related dependent variables are obtained through questionnaire survey instruments. From the responses of SF-36v2, two variables of the Physical Component Score (PCS) and Mental Component Score (MCS) are derived to reflect the general physical and mental health status, respectively (Ware et al. 2008). In Hong Kong, Singapore, and Tokyo, the validated Chinese, English, and Japanese versions were used, respectively. Both PCS and MCS have a range of 0 to 100, with higher scores suggesting better health, but there is no cutoff point to classify healthy and unhealthy seniors.

Independent Variables: Factors at Individual, Neighborhood, and City Levels

For general physical and mental health, personal characteristics have long been identified as major risk factors, but there is a growing literature on the neighborhood factors (Ellen, Mijanovich, and Dillman 2001; Wen, Hawkley, and Cacioppo 2006). In this study, personal characteristics related to the individuals, families, and homes are collected. They include many demographic and socioeconomic characteristics of gender, age, height, weight, medical history, educational level, home location, living arrangements, household car ownership, weekly activities, and level of physical activity. The data collected through the International Physical Activity Questionnaire (IPAQ) Short Form are used to calculate the total physical activity in metabolic equivalent (MET), as well as its components of vigorous, moderate, and walking exercises (Booth et al. 2003). Based on MET, seniors are grouped into the inactive (MET < 600), minimally active ($3,000 >$ MET ≥ 600), and active (MET $\geq 3,000$) groups to reflect their lifestyle (ACTIVE). In addition, based on body mass index (BMI), seniors are also classified as underweight (BMI < 18.5), normal weight ($25 >$ BMI ≥ 18.5), overweight ($30 >$ BMI ≥ 25), and obese (BMI ≥ 30). Those who reported three or more bodily pains and chronic illnesses are identified (PAIN). In addition, seniors' weekly activity patterns are analyzed. In relation, their employment status (WORK) and whether they are sociable (SOCI) are captured. For SOCI, those who engaged in zero or one day, two to four days, and five to seven days a week in social and recreational activities are considered not sociable, moderately sociable, and very sociable, respectively. We also observed whether the seniors were using any walking aid (WAID).

Next, respondents' subjective perceptions about their local neighborhood are captured. This study advocates the concept of people-based rather than administratively defined neighborhood. To geographers, district or zonal-level variations are too crude and might not truly reflect the experiences of people about their neighborhood (Kwan 2012). Following the geographical framework of a multiscale living environment, we develop new ways of capturing the characteristics of a local neighborhood in a geographic information system (GIS). The first set of neighborhood characteristics is individual specific, reflecting the immediate surroundings of one's home and one's perceptions or personal experiences with people living in the same community. They are called individual-based local characteristics (later referred to as Level 1 local factors). The second set of neighborhood characteristics is more general, reflecting common and general conditions of a local area that people in a neighborhood share. They are labeled general local characteristics (later referred to as Level 2 local factors).

For the first set of local characteristics, each participant's neighborhood covers the nearby areas with one's home. Given that walking is the main transport mode that seniors use to move within their neighbourhood, a 500-m (or roughly a ten-minute walk) GIS buffer is generated based on the specific pedestrian networks of the home areas (vs. the crow-fly distance used in many existing studies). Within this neighborhood area accessible by walking, we focus on four

major dimensions that are directly relevant to the daily life of seniors. The first dimension captures some key principles in urban planning: density (DEN), diversity (DIV), and design (DES; Cervero and Kockelman 1997). For density, this study considers population density (DEN) where higher density implies more population to support a vibrant neighborhood. Yet, it could also lead to stress and problems related to overcrowding. Diversity refers to the mixture of land use in contributing to balanced development. It is calculated using Simpson's Diversity Index as an entropy measure by considering five categories of land use—residential, commercial, institutional, recreational, and others (DIV; Simpson 1949; Loo and Lam 2013). Good design relates to the attractiveness of the neighborhood environment. It includes connectivity expressed in terms of the number of road intersections per square kilometer (DES1) and the percentage of open space in one's neighborhood (DES2). On one hand, higher connectivity (DES1) provides pedestrians more alternative routes. On the other hand, it implies more road junctions, which might entail additional challenges and risks of crossing roads (Loo and Tsui 2016). Open space near home (DES2) can encourage more walking, social contact, and interaction (Gieryn 2002). These data are measured objectively on a pro rata basis using GIS. The second dimension is the network distance or walking time to facilities that are relevant to the daily life of older people living independently. They include the nearest medical facility (DIS1), entrance to a green or open space (DIS2), supermarket (WKT1), and public transport stop or station (WKT2).

The third and fourth dimensions are perceived walkability and social capital, both related to subjective perceptions. As mentioned earlier, walking is the most important means for seniors to move around in their neighbourhood and is of crucial importance in supporting aging in place. Following Loo and Lam (2012), fifteen subjective walkability variables evolving around overall walkability (SOW) and its key components of safety (SW1–6, including heavy vehicular traffic, short green road-crossing time, local crime, poor sidewalk, too many slopes, poor lighting at night), convenience (SW7–8 including the availability of alternative walking routes and clear signage), and comfort (SW9–14 including street crowdedness, availability of cover for pedestrian walkways, air pollution, availability of greenery, availability of nice views, and cleanliness of pavements) are collected. Apart from the subjective overall walkability (SOW) that varies from 0 to 100, all walkability variables are

scored on a scale of one to five, with one suggesting good (e.g., pavements are clean) or poor (e.g., pavements are dirty), and reversed randomly to avoid the response pattern syndrome in questionnaire design. A final dimension is social capital (SC), which is primarily about people's relations with each other in their local neighborhood. Social capital is referred to as the resources such as norms, trust, and social ties that are available to members of a neighborhood (Kawachi, Subramanian, and Kim 2008). Previous research studies have suggested a close relationship between physical activity and social capital (Leyden 2003). In this study, four social capital variables are captured. Three of them are measured by a five-point Likert scale on the statements, "People in my neighborhood get along with each other well" (SC1), "People are willing to help each other" (SC2), and "Living in this neighborhood gives me a sense of community" (SC3). The last question asks whether the senior has a companion to go about with (SC4). The four SC variables are about the subjective feelings of seniors and the degree to which they see themselves as involved and are able to rely on other residents in their neighborhood.

Up to here, each neighborhood is individual specific. It has the key advantage of being more people-centered, but it ignores the fact that individuals share common neighborhoods. Hence, some spatial aggregation is also done by mapping individual buffers in GIS to identify larger common (overlapped) neighborhoods for the seniors in our sample. When the individual buffers overlap, a common neighborhood is formed. To avoid having too large a neighborhood, the maximum size of a neighborhood is set to be a total area of 3 km^2 (a radius of about 1 km). Neighborhoods with too few people (notably less than ten) are also discarded for further analysis. For this second set of local characteristics, variables are designed to capture the general or average situation of people living within a shared neighborhood. To illustrate, age is a characteristic at the individual level but the share of oldest-old (eight-five or older) becomes a characteristic at the neighborhood level. This second set of general local characteristics is highly relevant, as well, in informing us about the mesoscale geographical environment. They include variables of the demographic (NDM1–2 including shares of oldest-old of eighty-five years or older and women), nondemographic (NND1–7 including shares of underweight and obese, those with an active lifestyle, those having at least one car, living alone, illiterate, working, and being very sociable), attitudinal (NAT1–18 including means of all

SW and SC variables), urban planning (NUP1–4 including means of DEN, DIV, DES1, and DES2), facilities (NUP5–8 including means of DIS1, DIS2, WKT1, WKT2), and objective walkability (NOW and NW1–8 including the composite score and its components of the presence of sidewalk, street activities, signage, sidewalk width, sidewalk surface, greenery, availability of seats, and road-crossing width) dimensions. The objective walkability assessments were done following a set of fieldwork protocols, described in Loo and Lam (2012). Combining the two sets of supplementary neighborhood variables, the local neighborhood is more relevant and specific to the seniors but not so fine as to make it distinct for each individual.

Finally, nine city-level factors including area, population size, population density, income (including gross domestic product and average household income per capita), life expectancy (for men and women), and weather conditions (including average rainfall and temperature) are collected for the multilevel analysis.

Multilevel Analysis

To disentangle the effects of independent variables operating at different spatial scales, multilevel analysis is used. To conduct the multilevel analysis, the variables are input based on the statistical units used. Personal and individual-based local variables, which vary by subject, are input as Level 1 variables (the statistical unit is an individual). Then, all general local attributes are considered as Level 2 variables (the statistical unit is a distinct local neighborhood). Finally, all city-level variables are considered as Level 3 variables (the statistical unit is a city). For each of the two health variables, one three-level (city–neighborhood–individual) and two two-level (city–individual and neighborhood–individual) hierarchical linear models are tested. HLM 7 is used in conducting the multilevel analysis and generating the key statistics for calculating the summary indexes for comparing different model fits. In selecting the best model, we are guided by the proportion variance explained at successive levels and the number of statistically significant independent variables identified. Moreover, as the data set gathered is very large, multicollinearity is likely to exist if variables are not included in a prudent manner. Bivariate analysis was conducted for each independent health variable and only statistically significant variables at 95 percent are tested first. In addition, some

variables like population density and income are very large and are subsequently transformed by logarithm before the analysis. Despite these efforts, the process of finding the best models is still highly demanding intellectually and statistically, as there are always possible alternative models. The final best models for both PCS and MCS are the neighborhood–individual (two-level) models, probably reflecting and confirming the importance of local contexts at the mesoscale and personal factors in understanding the health status of seniors in cities.

Results

Descriptive Statistics

After data editing and cleaning, the total sample size of this study is 607, with 188, 180, and 239 living in Hong Kong, Tokyo, and Singapore, respectively. With regard to the health variables, the mean PCS is 70.13 and the mean MCS is 77.29. A scatterplot of PCS and MCS shows that there is a positive relationship between mental and physical health (Figure 3) but the R^2 is not particularly high at 0.46 ($p = 0.00$). As both PCS and MCS are above 70, the physical and mental health of the participants are relatively good. In particular, the average MCS is nearly 80, suggesting a mentally healthy group of senior participants in all three Asian cities.

Table 1 shows some selected descriptive statistics of the PCS and MCS by city and personal characteristics. Based on the two health scores, respondents in Tokyo have better physical ($\overline{PCS} = 74.80$) and mental health ($\overline{MCS} = 80.20$). Generally, the health status of men ($\overline{MCS} = 79.61$ and $\overline{PCS} = 73.33$) is better than women ($\overline{MCS} = 76.60$ and $\overline{PCS} = 69.18$). Moreover, the physical health status of the seniors declines systematically with advancing age after seventy-five years old. $\overline{PCS}$ drops systematically from 71.36 for the seventy-one- to seventy-five-year-old group to 64.63 for the above eighty-five-year-old group. This aging pattern in mental health is less clear. As expected, the health scores of respondents living alone ($\overline{PCS} = 69.33$ and $\overline{MCS} = 76.74$) are lower than their counterparts ($\overline{PCS} = 70.41$ and $\overline{MCS} = 77.46$). Overweight ($\overline{PCS} = 66.30$ and $\overline{MCS} = 76.60$) and obese ($\overline{PCS} = 58.59$ and $\overline{MCS} = 70.61$) respondents have poorer physical and mental health. Moreover, the level of physical activities also seems to matter, with the health
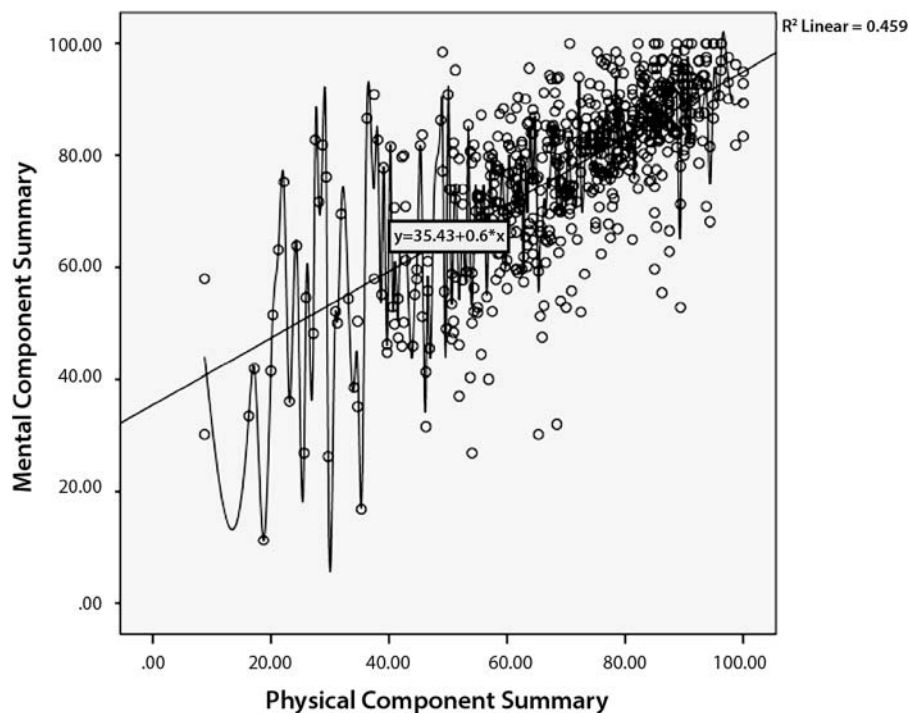
Figure 3. A scatterplot of physical and mental component scores among survey participants.

scores being the highest for the active group ($\overline{PCS}$ = 72.00, $\overline{MCS}$ = 79.58) and the lowest for the inactive group ($\overline{PCS}$ = 69.19, $\overline{MCS}$ = 75.57).

Altogether, this study includes eleven distinct local neighborhoods in the three Asian cities, as listed in Table 2. Participants who did not belong to a distinct neighborhood are excluded. Next, Table 3 shows the descriptive statistics of some major Level 2 local variables. In terms of population density (NUP1), the sample varies from a high

Table 1. Summary statistics of health variables by city and personal characteristics

		N	%	Mean PCS ($\overline{PCS}$)	Mean MCS ($\overline{MCS}$)
All		607	100.00	70.13	77.29
City	Hong Kong	188	30.97	65.84	76.83
	Tokyo	180	29.65	74.80	80.20
	Singapore	239	39.37	70.18	77.29
Gender	Male	140	23.06	73.33	79.61
	Female	467	76.94	69.18	76.60
Age group	70 or below	180	29.65	70.29	76.18
	71–75	180	29.65	71.36	78.83
	76–80	156	25.70	70.17	77.48
	81–85	66	10.87	68.47	74.48
	Above 85	25	4.12	64.63	78.02
Living alone	Yes	168	27.68	69.33	76.74
	No	437	71.99	70.41	77.49
BMI	Underweight	36	5.93	72.55	75.42
	Normal range	391	64.42	72.18	78.17
	Overweight	155	25.54	66.30	76.60
	Obese	25	4.12	58.59	70.61
Lifestyle	Inactive	147	24.22	69.19	75.57
	Minimally active	315	51.89	69.71	77.04
	Active	145	23.89	72.00	79.58

Note: PCS = physical component score; MCS = mental component score; BMI = body mass index.

Table 2. Sample characteristics of local neighborhoods

City	Number of neighborhoods	Average size of neighborhood (km²)	Valid sample size
Hong Kong	4	2.11	173
Singapore	3	1.20	171
Tokyo	4	2.38	161
Total	11	1.92	505

of 102,577 people/km^2 in Hung Hom, Hong Kong, to a low of 6,678 people/km^2 in Tai Po, Hong Kong. The diversity of land use is the highest in Sai Ying Pun, Hong Kong (NUP2 = 0.68), and the lowest in Jurong West Central, Singapore (NUP2 = 0.27). The road connectivity (NUP3) varies from the highest in Oiumi, Tokyo (NUP3 = 345.63), to the lowest in Hong Kah, Singapore (NUP3 = 96.70). The public open space ratio was the highest in Tai Po, Hong Kong (NUP4 = 9.82), and the lowest in Shakuji-dai, Tokyo (NUP4 = 1.65). The distance to the nearest medical facility is the longest in Sekimachi, Tokyo (NUP5 = 724.50), and the shortest in Hong Kah, Singapore (NUP5 = 192.41); and distance to the nearest public open space are the longest in Hung Hom, Hong Kong (NUP6 = 389.21), and the shortest in Lai Chi Kok, Hong Kong (NUP6 = 128.12). Walking time to the nearest supermarket (NUP7) is the shortest in Lai Chi Kok, Hong Kong (6.03

minutes), and the longest in Hong Kah, Singapore (13.82 minutes). Walking time to the nearest public transport stops and stations (NUP8) is the shortest in Sekimachi, Tokyo (4.20 minutes), and the longest in Jurang West Central, Singapore. Finally, the overall walkability score (NOW) of all neighborhoods in this study was 72.93. It was the highest in Kami-Shakujii, Tokyo (78.99), and the lowest in Lai Chi Kok, Hong Kong (66.05). Overall, the neighborhoods included in this study seem to be able to capture the diversity of different local contexts among the three cities. No distinct neighborhood or city is found to have the best or worst performance in terms of all urban planning and walkability aspects.

Multilevel Analysis

Before the results of the two final health models are described in detail, several statistical fit indexes based on the variance components are listed in Table 4 (Department of Statistics and Data Sciences 2015; Scientific Software International 2015). They are the −2 log-likelihood, deviance, intraclass correlation coefficient ($\hat{\rho}$), proportion of variance explained at Level 1 ($\hat{u}_1$), proportion of variance explained at Level 2 ($\hat{u}_2$), and the conditional $\hat{\rho}$ after adding the Level 2 predictors.

Table 3. Summary statistics of general local variables

	NUP1	NUP2	NUP3	NUP4	NUP5	NUP6	NUP7	NUP8	NOW
Hong Kong									
Sai Ying Pun (N1)	74,367	0.68	253.98	5.11	346.31	201.85	8.80	5.69	67.26
Hung Hom (N2)	102,577	0.50	235.39	5.37	655.21	389.21	8.70	5.73	67.76
Lai Chi Kok (N3)	72,141	0.52	212.25	5.21	321.39	128.12	6.03	4.26	66.05
Tai Po (N4)	6,678	0.26	130.47	9.82	683.83	268.45	6.73	5.76	74.17
Singapore									
Jurong West Central (N5)	63,016	0.27	143.99	5.58	426.41	243.57	11.56	9.55	74.08
Boon Lay (N6)	29,288	0.41	181.83	2.11	366.32	368.44	11.65	9.38	69.29
Hong Kah (N7)	30,298	0.41	96.70	3.70	192.41	268.99	13.82	8.87	72.27
Tokyo									
Shakujii-dai (N8)	16,047	0.54	245.58	1.65	414.63	193.83	6.81	6.54	78.38
Sekimachi (N9)	15,302	0.48	249.72	2.44	724.50	266.20	6.85	4.20	78.99
Oizumi (N10)	14,292	0.51	345.63	1.82	623.24	264.17	7.86	6.61	74.12
Kami-Shakujii (N11)	15,913	0.47	263.04	1.91	419.92	266.40	7.60	6.46	79.82
Entire sample									
Total	39,993	0.46	214.42	4.06	470.38	259.93	9.09	6.83	72.93

Note: NUP1 = population density in people per square kilometer; NUP2 = land use diversity from 0 to 1; NUP3 = road connectivity in junctions per square kilometer; NUP4 = open space availability as share of neighborhood area from 0 to 1; NUP5 = average network distance to the nearest medical facility in meters; NUP6 = average network distance to the nearest public park entrance in meters; NUP7 = self-reported travel time to the nearest supermarket in minutes; NUP8 = self-reported travel time to the nearest public transport stops or stations in minutes; NOW = objective overall walkability from 0 to 100.

Table 4. Key statistical fit indexes of the final PCS and MCS multilevel analysis

	PCS	MCS
Model 1 (fully unconditional)		
−2 log-likelihood	−2,158.26	−2,081.94
Deviance	4,316.51	4,163.87
Model 2 (with Level 1 variables only)		
−2 log likelihood	−2,001.98	−1,951.53
Deviance	4,003.96	3,903.06
Model 3 (with Level 2 variables only)		
−2 log-likelihood	−2,149.68	−2,077.94
Deviance	4,299.37	4,155.87
Model 4 (final model with all variables)		
−2 log likelihood	−1,982.34	−1,946.94
Deviance	3,964.68	3,893.87
Overall model fit		
$\hat{\rho}$	0.1753	0.0824
$\hat{u}_1$	0.1306	0.0750
$\hat{u}_2$	0.6899	0.8681
Conditional $\hat{\rho}$	0.08	0.0172

Note: PCS = physical component score; MCS = mental component score.

From Table 4, the value of the intraclass correlation coefficient ($\hat{\rho}$) for the final PCS and MCS model is 0.1753 and 0.0824, respectively, suggesting that 17.53 percent and 8.24 percent of the variance in health scores is across general neighborhoods. In other words, most of the variability is still observed at the individual level, including personal and individual-based neighborhood factors. Nonetheless, general local factors are still quite important in explaining physical health status, with nearly 18 percent of the variability over different neighborhoods. The relationship between mental health and the general neighborhood factors is weaker, but still about 10 percent of the variability lies here. If the inclusion of general neighborhood factors significantly increases the explanatory power of the model, both the −2 log-likelihood and deviance will be reduced. The larger the reduction, the higher the explanatory power. From Table 4, both the −2 log-likelihood and deviance decrease when Model 1 and Model 4 are compared. The ratio of the reduction of deviance is 8.15 percent (from 4,316.51 to 3,964.68) for PCS and 6.48 percent (from 4,163.87 to 3,893.87) for MCS. For PCS, $\hat{u}_1$ and $\hat{u}_2$ suggest that the final Level 2 variables included (discussed later) accounted for 13.06 percent of the proportion of variance explained at the individual level and they accounted for 68.99 percent of the proportion of variance explained at the general neighborhood level. Although the impact of general local variables is less significant on MCS ($\hat{\rho} = 0.0824$, $\hat{u}_1 = 7.50$ percent), the final Level 2 variables included (shown in Tables 5 and 6) managed to capture the general neighborhood variability better at 86.81 percent ($\hat{u}_2 = 0.8681$). This finding is also supported by the values of conditional $\hat{\rho}$, as the differences between the conditional $\hat{\rho}$ and $\hat{\rho}$ reflect the significance of Level 2 variables in reducing the variability of the outcome variables. The larger the difference, the more meaningful the Level 2 variables included. In the case of PCS, $\hat{\rho}$ is about 2.2 times higher than the conditional $\hat{\rho}$. In the case of MCS, the ratio is even higher, at 4.8 times.

The following equation shows the final multilevel analysis of PCS as a mixed model:

$$
\begin{aligned}
PCS_{ij} = {} & \gamma_{00} + \gamma_{01} * NOW_j + \gamma_{10} * BMI_{ij} + \gamma_{11} \\
& * SOW_j * BMI_{ij} + \gamma_{12} * LDEN_j * BMI_{ij} + \gamma_{20} \\
& * ACTIVE_{ij} + \gamma_{21} * NW5_j * ACTIVE_{ij} + \gamma_{22} \\
& * NSOCIAL_j * ACTIVE_{ij} + \gamma_{30} * PAIN_{ij} \\
& + \gamma_{40} * SC2_{ij} + \gamma_{50} * SC3_{ij} + \gamma_{60} * WKT1_{ij} \\
& + \gamma_{70} * SW5_{ij} + \gamma_{80} * WAID_{ij} + \gamma_{90} \\
& * WEIGHT_{ij} + u_{0j} + u_{1j} * BMI_{ij} \\
& + u_{2j} * ACTIVE_{ij} + r_{ij}.
\end{aligned}
$$

The variable notations follow the preceding methodology; the Level 1 intercept and error terms are denoted by γ_{00} and u_{0j}; all Level 1 coefficients are denoted by i; Level 2 coefficients are denoted by j. All variables are considered as random variables. With this mixed model, the coefficients and associated statistics are listed in Table 5.

At Level 1, there are nine statistically significant variables at the 95 percent confidence level. There are five personal factors in relation to BMI, lifestyle (ACTIVE), self-reported medical history (PAIN), use of walking aid (WAID), and weight (WEIGHT), as well as four individual-based neighborhood factors in relation to social capital (SC2 and SC3), travel time to the nearest supermarket (NWT1), and too many slopes (SW5).

First, overweight in relation to an individual's height (BMI) is negatively associated with physical health. Nonetheless, seniors in Asia should also be alerted to have a balanced diet and not be overly worried about gaining weight because absolute weight (WEIGHT), after controlling for BMI, is positively associated with good health. The use of a walking aid (WAID) is positively associated with PCS, suggesting that seniors who

Table 5. Results of the physical component score multilevel analysis

Fixed effect	Coefficient	Standard error	t ratio	Approx. df	p value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	70.429589	0.784667	89.757	9	<0.001
NOW, γ_{01}	12.287764	2.431599	5.053	9	<0.001
For BMI slope, β_1					
INTRCPT2, γ_{10}	−1.406808	0.350601	−4.013	8	0.004
SOW, γ_{11}	0.173797	0.077305	2.248	8	0.055
LDEN, γ_{12}	2.446848	0.889865	2.750	8	0.025
For ACTIVE slope, β_2					
INTRCPT2, γ_{20}	2.843219	1.145230	2.483	8	0.038
NW5, γ_{21}	−10.907586	4.020857	−2.713	8	0.027
NND7, γ_{22}	−0.255536	0.082662	−3.091	8	0.015
For PAIN slope, β_3					
INTRCPT2, γ_{30}	−7.282968	1.692549	−4.303	446	<0.001
For SC2 slope, β_4					
INTRCPT2, γ_{40}	2.092312	0.810214	2.582	446	0.010
For SC3 slope, β_5					
INTRCPT2, γ_{50}	1.860072	0.851527	2.184	446	0.029
For WKT1 slope, β_6					
INTRCPT2, γ_{60}	−1.414759	0.644008	−2.197	446	0.029
For SW5 slope, β_7					
INTRCPT2, γ_{70}	2.512698	0.746147	3.368	446	<0.001
For WAID slope, β_8					
INTRCPT2, γ_{80}	15.522622	2.075646	7.478	446	<0.001
For WEIGHT slope, β_9					
INTRCPT2, γ_{90}	0.257091	0.079323	3.241	446	0.001

need to use a walking aid are often healthy physically; they should not be discouraged from moving around. Self-reported bodily pains and medical conditions (PAIN) are negatively associated with PCS. Although this factor might be considered as a consequence of poor physical

Table 6. Results of the mental component score multilevel analysis

Fixed effect	Coefficient	Standard error	t ratio	Approx. df	p value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	78.115514	0.634121	123.187	8	<0.001
NOW, γ_{01}	4.755452	2.001721	2.376	8	0.045
N_BMIG, γ_{02}	−0.301606	0.126366	−2.387	8	0.044
For BMI slope, β_1					
INTRCPT2, γ_{10}	−0.704466	0.298493	−2.360	465	0.019
For SC2 slope, β_2					
INTRCPT2, γ_{20}	1.623520	0.758699	2.140	465	0.033
For SC3 slope, β_3					
INTRCPT2, γ_{30}	2.371428	0.795983	2.979	465	0.003
For SC4 slope, β_4					
INTRCPT2, γ_{40}	3.332332	1.620691	2.056	465	0.040
For WKT1 slope, β_5					
INTRCPT2, γ_{50}	−1.670864	0.602802	−2.772	465	0.006
For SW5, β_6					
INTRCPT2, γ_{60}	1.771529	0.698942	2.535	465	0.012
For WAID slope, β_7					
INTRCPT2, γ_{70}	8.060248	1.925140	4.187	465	<0.001
For WEIGHT slope, β_8					
INTRCPT2, γ_{80}	0.209016	0.068443	3.054	465	0.002

health, we include is in the model because it is collected independently from SF-36v2 and is a very simple self-reported measure that is easy to obtain. These data can help local senior community centers to identify particularly vulnerable groups. Statistically, it also acts as an important control factor. Then, having an active lifestyle (ACTIVE) is significant. The sign of the estimated coefficient is positive, suggesting that more physically active seniors do enjoy better physical health. Social capital is very important, with seniors feeling more positive about their neighborhood that people are willing to help each other (SC2) and those having a sense of community (SC3) being more healthy. Moreover, seniors who considered their neighborhoods as having many slopes or stairs that make them feel insecure to walk (SW5) were less healthy. At this point, it is perhaps worth mentioning that living alone (ALONE), education level (ILLITERATE), and age (OLDEST) were tested but not significant and not included in the final model.

At Level 2, there are a few statistically significant variables at a 95 percent confidence level. The first one is the overall objective walkability of the neighborhood obtained from a walkability audit (NOW). The coefficient is positive, suggesting that seniors living in a walkable neighborhood do tend to have better physical health. The average perceived and subjective walkability of the neighborhood near one's home (SOW) and population density (LDEN or log of NUP1) are significant interaction factors in explaining BMI. The coefficients are both positive, with SOW being just marginally not significant at the 0.05 level ($p = 0.055$). In other words, seniors perceiving their neighborhoods as not walkable and those living in neighborhoods with lower population density tend to have higher BMI. A previous study suggests that those living in higher density neighborhoods undertake higher levels of walking, and more walking predicted lower BMI (Li et al. 2005). In addition, lifestyle (ACTIVE) is associated with two general neighborhood factors in relation to the quality of the sidewalk road surface (whether smooth, rough, or uneven, NW5) and the share of sociable seniors within the same community (NND7).

Thus, uneven pedestrian surfaces should be addressed if the seniors are to be more active physically. Outdoor pedestrian fall-related injuries have been a major concern for elderly people (Gyllencreutz et al. 2015). Moreover, having "senior ambassadors" or a group of active seniors in a community also helps to encourage other seniors to have a more active lifestyle.

For MCS, the results of the final multilevel analysis are expressed as a mixed model:

$$MCS_{ij} = \gamma_{00} + \gamma_{01} * NOW_j + \gamma_{02} * NBMIG_j + \gamma_{10} \\ * BMI_{ij} + \gamma_{20} * SC2_{ij} + \gamma_{30} * SC3_{ij} + \gamma_{40} \\ * SC4_{ij} + \gamma_{50} * WKT1_{ij} + \gamma_{60} * SW5_{ij} + \gamma_{70} \\ * WAID_{ij} + \gamma_{80} * WEIGHT_{ij} + u_{0j} + r_{ij}.$$

The coefficients and associated statistics of the final MCS multilevel analysis are shown in Table 6. Altogether, there are ten independent variables significant at a 95 percent confidence level. Three of them (BMI, WAID, and WEIGHT) are personal factors, five are individual-based neighborhood factors (SC2, SC3, SC4, WKT1, and SW5), and two are general neighborhood factors (NOW and NBMIG). In the first place, it is important to highlight that overweight (BMI) is associated not only with poor physical health but with poor mental health. In contrast, the use of a walking aid (WAID) is not associated with poorer mental health, and seniors who might need to use a walking aid can still actively participate in the local neighborhood and enjoy a satisfying life. In addition, having a healthy diet and reasonable weight (WEIGHT), after controlling for BMI, is important in explaining a mentally healthy senior. Similar to the PCS model, social capital is found to be very important, with seniors feeling more positively about their neighborhood that people are willing to help each other (SC2) and those having a sense of community (SC3) being more healthy. SC4—that is, having a companion to go about and outside home with—is statistically significant at a 95 percent confidence level in the MCS model. The coefficient is positive, suggesting that having a companion to go outside with is significantly associated with better mental health. This is independent of the living arrangements (e.g., ALONE). In other words, these walking companions are not mainly domestic helpers or family members living together. Once again, a perception of too many slopes in the neighborhood (SW5) is negatively associated with mental health. PAIN and ACTIVE are not statistically significant at the 0.05 level, probably

suggesting that seniors with a more sedentary life-style might have other less active hobbies like chess and calligraphy or have other family and social activities that give them satisfaction and keep them mentally healthy.

At Level 2, all interaction terms tested are not statistically significant at the 0.05 level. The two statistically significant general local factors in explaining the variability of the mental health score are the neighborhood's objective walkability (NOW, again) and the share of elderly not within the normal weight range of BMI ($25 > BMI \geq 18.5$; NBMIG). When a senior navigates in his or her neighborhood, many environmental factors, such as weather, the closing down of shops, and new land development, are likely to stimulate con-versations with people and generate social interac-tions that help to reduce feelings of loneliness for seniors. Similarly, seniors living in a community with more peers in the normal weight range tend to have better mental health. Communities or neighborhoods with a high concentration of under-weight or overweight (including obese) seniors are worth closer investigation. A community-based weight control program can serve the purpose of identifying target elderly and initiating appropriate intervention strategies at an early stage (Joo and Kim 2007).

Conclusion

Most seniors expressed a desire to live in their own homes as long as possible (Morley 2016). Yet, as old people get older, many of their physical and cognitive functions will decline. To policymakers, the urban infrastructure, not just within homes but also the neighborhood, needs to be modified to compensate for the functional limitations and dis-abilities among the geriatric population in cities. Without turning cities into "the land of old age" with nursing homes and institutionalizing the elderly population (Laws 1993), there needs to be extra support in the urban living environment to facilitate community-dwelling seniors to have an active old-age life with good mental and physical functioning. This article also represents an innova-tive way of conceptualizing and measuring neigh-borhoods in a new manner at the individual-based (Level 1) and general (Level 2) levels so that the association between health and urban environment can be better disentangled.

First, personal factors are of great importance in affecting the physical and mental health of commu-nity-dwelling seniors. "Unchangeable" biological factors such as gender and age, however, do not seem to be the most important. Instead, having a normal range of weight (BMI) and the proper use of a walking aid (WAID) can allow seniors, even of the oldest-old group of eighty-five years or older, to be more active in the community (e.g., in join-ing local senior community centers) and be health-ier both physically and mentally. This is a noteworthy finding given that frail elderly are con-sistently depicted to be unconnected with other group members in the society (Weisman and Schwartz 1989). Local governments and commu-nity-based organizations should look for ways to encourage them to stay connected with people in their communities and live active, social, and ful-filling lives.

Second, although this research covers three major Asian metropolitan cities with very different cultures (including the Chinese and Japanese cul-tures), climate (e.g., temperate in Tokyo vs. tropi-cal in Singapore), and other geographical contexts, the association of local neighborhood factors with health is independent of the city in which the seniors are living. Regardless of the heterogeneity observed among seniors in the three cities, neigh-borhood factors, particularly in terms of subjective perceptions of the local community, are important in affecting both seniors' health directly through subjective walkability (SOW and SW5) and peer group influence (e.g., NND7 and NBMIG) and indirectly through their lifestyle (ACTIVE). Fur-thermore, the results of this article echo previous works that suggest that social capital is closely linked to health outcomes (Cannuscio, Block, and Kawachi 2003; Pollack and von dem Knesebeck 2004). When planning for local communities, facilities and activities that help to promote social capital should be provided to support healthy aging in place. In particular, seniors who feel that people living in the neighborhood are helpful (SC2) and those having a sense of community near their homes (SC3) have both better physical and mental health. Moreover, neighbors in the same community can be encouraged to walk together (SC4) as "walking buddies" to achieve multiple health benefits.

Third, this study draws on a multilevel approach emphasizing multiple geographical scales

in understanding the health of seniors. This new conceptualization is reproducible within and between localities for unleashing the individual-level and general neighborhood effects. So far, much of the work about neighborhood effects has been of an aggregate nature (Pickett and Pearl 2001). The need to recognize and measure neighborhood factors with reference to the daily life of the seniors and beyond administrative boundaries and standard statistical units is underlined. Hence, a multilevel policy to support aging in place should go beyond visiting seniors at home and modifying their home environment to making the general neighborhood environment supportive and pleasant.

Last but not least, promoting an objectively walkable neighborhood (NOW) with smooth surfaces (NW5; e.g., through walkability audits) by enhancing the comfort, convenience, and safety of pedestrians (including those using walking aids or wheelchairs on pedestrian walkways) should be a priority policy area for governments aiming to support or promote healthy aging in place. In addition, this research article has addressed the methodological challenges of an integrated spatial analysis by combining perceived and objective measures. On the one hand, it captured important information about individuals' relationships with their environment through questionnaire surveys. On the other hand, it collected different objective neighborhood information through microscale walkability assessments and various land use data. These general local characteristics can, in turn, be modified by policy interventions. Finally, through combining different data, the multilevel spatial framework has allowed for a more systematic evaluation of the independent and combined effects of various subjective and objective urban environmental attributes on the physical and mental health of seniors.

Funding

ORCID

Becky P. Y. Loo 🆔 http://orcid.org/0000-0003-0822-5354

References

Alsnih, R., and D. A. Hensher. 2003. The mobility and accessibility expectations of seniors in an aging population. *Transportation Research Part A: Policy and Practice* 37 (10): 903–16.

Ameratunga, S., M. Hijar, and R. Norton. 2006. Road-traffic injuries: Confronting disparities to address a global-health problem. *The Lancet* 367 (9521): 1533–40.

Booth, M. L., B. E. Ainsworth, M. Pratt, U. Ekelund, A. Yngve, J. F. Sallis, and P. Oja. 2003. International Physical Activity Questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise* 35 (8): 1381–95.

Burton, E. J., L. Mitchell, and C. B. Stride. 2011. Good places for ageing in place: Development of objective built environment measures for investigating links with older people's wellbeing. *BMC Public Health* 11 (1): 1–13.

Cabinet Office of Japan. 2007. *International comparison survey on elderly people's livelihood and consciousness.* Tokyo: Cabinet Office of Japan.

Cannuscio, C., J. Block, and I. Kawachi. 2003. Social capital and successful aging: The role of senior housing. *Annals of Internal Medicine* 139 (5): 395–99.

Census and Statistics Department. 2012. *Hong Kong population projections, 2012–2041.* Hong Kong: Census and Statistics Department.

Cervero, R., and K. Kockelman. 1997. Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment* 2 (3): 199–219.

Coughlin, J. 2001. *Transportation and older persons: Perceptions and preferences: A report on focus groups: AARP.* Washington, DC: Public Policy Institute.

Cummins, R. A. 1996. The domains of life satisfaction: An attempt to order chaos. *Social Indicators Research* 38 (3): 303–28.

Department of Statistics and Data Sciences, The University of Texas at Austin. 2015. Statistical consulting. Multilevel modelling tutorial: Using SAS, Stata, HKM, R, SPSS and Mplus. https://stat.utexas.edu/images/SSC/documents/SoftwareTutorials/MultilevelModeling.pdf (last accessed 10 December 2015).

Department of Statistics Singapore. 2015. *Population trends 2014.* Singapore: Department of Statistics. http://www.singstat.gov.sg (last accessed 15 September 2015).

Ellen, I. G., T. Mijanovich, and K. N. Dillman. 2001. Neighborhood effects on health: Exploring the links and assessing the evidence. *Journal of Urban Affairs* 23 (3–4): 391–408.

Freidan, B. 1963. *The feminine mystique*. New York: Dell.

Gieryn, T. F. 2002. What buildings do. *Theory and Society* 31 (1): 35–74.

Government of the Hong Kong Special Administrative Region. 2013. *Third quarter economic report 2013*. Hong Kong: Government of the Hong Kong Special Administrative Region.

Graafmans, J. 1998. Improving the quality of life for older people by design. *Gerontechnology: A Sustainable Investment in the Future* 48:74–104.

Gyllencreutz, L., J. Björnstig, E. Rolfsman, and B. I. Saveman. 2015. Outdoor pedestrian fall–related injuries among Swedish senior citizens—Injuries and preventive strategies. *Scandinavian Journal of Caring Sciences* 29 (2): 225–33.

Hirvensalo, M., T. Rantanen, and E. Heikkinen. 2000. Mobility difficulties and physical activity as predictors of mortality and loss of independence in the community–living older population. *Journal of the American Geriatrics Society* 48 (5): 493–98.

Hjorthol, R. J., L. Levin, and A. Sirén. 2010. Mobility in different generations of older persons: The development of daily travel in different cohorts in Denmark, Norway and Sweden. *Journal of Transport Geography* 18 (5): 624–33.

Housing & Development Board. 2016. *Jurong West—Price Range (Nov 2014)*. Singapore: Housing & Development Board. http://www101.hdb.gov.sg/hdbvsf/eampu11p.nsf/0/14NOVSBF_page_8877/$file/priceJW.htm (last accessed 22 January 2016).

IndexMundi. 2015. *Singapore demographic profile 2015*. Manchester, UK: IndexMundi. http://www.indexmundi.com (last accessed 17 September 2015).

Jackson, K. T. 1985. *Crabgrass frontier: The suburbanization of the United States*. New York: Oxford University Press.

Joo, N. S., and B. T. Kim. 2007. Mobile phone short message service messaging for behaviour modification in a community-based weight control programme in Korea. *Journal of Telemedicine and Telecare* 13 (8): 416–20.

Kawachi, I., S. V. Subramanian, and D. Kim. 2008. Social capital and health. In *Social capital and health*, ed. I. Kawachi, S. V. Subramanian, and D. Kim, 1–26. New York: Springer.

Kim, J. H., and J. H. Han. 2014. Myths of migration on retirement in Korea: Do the elderly move to less dense areas? *Habitat International* 41:195–204.

Kim, S., and G. Ulfarsson. 2004. Travel mode choice of the elderly: Effects of personal, household, neighborhood, and trip characteristics. *Transportation Research Record: Journal of the Transportation Research Board* 1894:117–26.

Kwan, M. P. 2012. The uncertain geographic context problem. *Annals of the Association of American Geographers* 102 (5): 958–68.

———. 2013. Beyond space (as we knew it): Toward temporally integrated geographies of segregation, health, and accessibility. Space–time integration in geography and GIScience. *Annals of the Association of American Geographers* 103 (5): 1078–86.

Lam, W. W. Y., S. Yao, and B. P. Y. Loo. 2014. Pedestrian exposure measures: A time–space framework. *Travel Behaviour and Society* 1 (1): 22–30.

Laws, G. 1993. "The land of old age": Society's changing attitudes toward urban built environments for elderly people. *Annals of the Association of American Geographers* 83 (4): 672–93.

Lee, D., and S. Cheah. 2016. Hong Kong women and men enjoy world's longest life expectancy due to low smoking rates, health experts claim. *South China Morning Post* 28 July 2016. http://www.scmp.com/news/hong-kong/health-environment/article/1995947/hong-kong-women-and-men-enjoy-worlds-longest-life (last accessed 28 July 2016).

Leyden, K. M. 2003. Social capital and the built environment: The importance of walkable neighborhoods. *American Journal of Public Health* 93 (9): 1546–51.

Li, F., K. J. Fisher, R. C. Brownson, and M. Bosworth. 2005. Multilevel modelling of built environment characteristics related to neighbourhood walking activity in older adults. *Journal of Epidemiology and Community Health* 59 (7): 558–64.

Loo, B. P. Y., and W. W. Y. Lam. 2012. Geographic accessibility around health care facilities for elderly residents in Hong Kong: A microscale walkability assessment. *Environment and Planning B: Planning and Design* 39 (4): 629–46.

———. 2013. A multilevel investigation of differential individual mobility of working couples with children: A case study of Hong Kong. *Transportmetrica A: Transport Science* 9 (7): 629–52.

Loo, B. P. Y., and K. L. Tsui. 2009. Pedestrian injuries in an ageing society: Insights from hospital trauma registry. *Journal of Trauma and Acute Care Surgery* 66 (4): 1196–1201.

———. 2016. Contributory factors to critically wrong road-crossing judgements among older people: An integrated research study. *Hong Kong Journal of Emergency Medicine* 23 (1): 13.

Lui, C. W., J. A. Everingham, J. Warburton, M. Cuthill, and H. Bartlett. 2009. What makes a community age-friendly: A review of international literature. *Australasian Journal on Ageing* 28 (3): 116–21.

Mayhew, D. R., H. M. Simpson, and S. A. Ferguson. 2006. Collisions involving senior drivers: High-risk conditions and locations. *Traffic Injury Prevention* 7 (2): 117–24.

Mollenkopf, H., A. Hieber, and H. W. Wahl. 2011. Continuity and change in older adults' perceptions of out-of-home mobility over ten years: A qualitative–quantitative approach. *Ageing and Society* 31 (5): 782–802.

Mori, Y., and M. Mizohata. 1995. Characteristics of older road users and their effect on road safety. *Accident Analysis & Prevention* 27 (3): 391–404.

Morley, J. E. 2016. Aging successfully: The key to aging in place. *JAMDA* 16:1005–1007.

Oleson, M. 1990. Subjectively perceived quality of life. *Image: The Journal of Nursing Scholarship* 22 (3): 187–90.

Phillips, D. R. 2002. *Ageing in the Asia–Pacific region: Issues, policies and future trends.* London and New York: Routledge.

Pickett, K. E., and M. Pearl. 2001. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: A critical review. *Journal of Epidemiology and Community Health* 55 (2): 111–22.

Planning Department. 2014. Chapter 10: Conservation 2014. http://www.pland.gov.hk/pland_en/tech_doc/hkpsg/full/ch10/ch10_text.htm (last accessed 15 September 2014).

Pollack, C. E., and O. von dem Knesebeck. 2004. Social capital and health among the aged: Comparisons between the United States and Germany. *Health & Place* 10 (4): 383–91.

Preusser, D. F., A. F. Williams, S. A. Ferguson, R. G. Ulmer, and H. B. Weinstein. 1998. Fatal crash risk for older drivers at intersections. *Accident Analysis & Prevention* 30 (2): 151–59.

Rosenbloom, S. 2003. *The mobility needs of older Americans: Taking the high road. A transportation agenda of strengthening metropolitan areas.* Washington, DC: The Brookings Institution.

Schwanen, T., and A. Páez. 2010. The mobility of older people—An introduction. *Journal of Transport Geography* 18 (5): 591–95.

Scientific Software International. 2015. *HLM7 hierarchical linear and nonlinear modeling.* Skokie, IL: Scientific Software International. http://www.ssicentral.com/ (last accessed 10 December 2015).

Sherman, J. E., J. Spencer, J. S. Preisser, W. M. Gesler, and T. A. Arcury. 2005. A suite of methods for representing activity space in a healthcare accessibility study. *International Journal of Health Geographics* 4 (1): 1.

Simpson, E. H. 1949. Measurement of diversity. *Nature* 163:688.

Smith, K. W., N. E. Avis, and S. F. Assmann. 1999. Distinguishing between quality of life and health status in quality of life research: A meta-analysis. *Quality of Life Research* 8 (5): 447–59.

Syed, S. T., B. S. Gerber, and L. K. Sharp. 2013. Traveling towards disease: Transportation barriers to health care access. *Journal of Community Health* 38 (5): 976–93.

Testa, M. A., and D. C. Simonson. 1996. Assessment of quality-of-life outcomes. *New England Journal of Medicine* 334 (13): 835–40.

United Nations. 2014a. World's population increasingly urban with more than half living in urban area. http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html (last accessed 12 September 2014).

———. 2014b. *World urbanization prospects: The 2014 revision.* New York: United Nations.

———. 2015. *World population ageing report 2015.* New York: United Nations.

Ware, J. E., M. Kosinski, J. B. Bjorner, D. M. Turner-Bowker, B. Gandek, and M. E. Maruish. 2008. *User's manual for the SF-36v2 Health Survey.* Lincoln: Quality Metric.

Weisman, C. B., and P. Schwartz. 1989. Worker expectations in group work with the frail elderly: Modifying the models for a better fit. *Social Work with Groups* 12 (3): 47–55.

Wen, M., L. C. Hawkley, and J. T. Cacioppo. 2006. Objective and perceived neighborhood environment, individual SES and psychosocial factors, and self-rated health: An analysis of older adults in Cook County, Illinois. *Social Science & Medicine* 63 (10): 2575–90.

Wiles, J. L., R. E. Allen, A. J. Palmer, K. J. Hayman, S. Keeling, and N. Kerse. 2009. Older people and their social spaces: A study of well-being and attachment to place in Aotearoa New Zealand. *Social Science & Medicine* 68 (4): 664–71.

World Bank. 2015. *Country and lending groups.* Washington, DC: World Bank. http://data.worldbank.org/about/country-and-lending-groups#High_income (last accessed 15 September 2015).

World Health Organization. 2013. *Global status report on road safety 2013: Supporting a decade of action.* Geneva: World Health Organization.

Yao, S., B. P. Loo, and W. W. Lam. 2015. Measures of activity-based pedestrian exposure to the risk of vehicle–pedestrian collisions: Space–time path vs. potential path tree methods. *Accident Analysis & Prevention* 75:320–32.

Zhang, J., J. Lindsay, K. Clarke, G. Robbins, and Y. Mao. 2000. Factors affecting the severity of motor vehicle traffic crashes involving elderly drivers in Ontario. *Accident Analysis & Prevention* 32 (1): 117–25.

BECKY P. Y. LOO is a Professor in the Department of Geography at The University of Hong Kong, Pokfulam, Hong Kong. E-mail: bpyloo@hku.hk. Her research interests are transportation, e-technologies, and society.

WINNIE W. Y. LAM is a Demonstrator in the Department of Geography at The University of Hong Kong, Pokfulam, Hong Kong. E-mail: lamwwy@hku.hk. Her research interest is socially sustainable transportation.

RATHI MAHENDRAN is a Senior Consultant Psychiatrist, Associate Dean at NUH, 119228 Singapore, and Associate Professor in the Department of Psychological Medicine at Yong Loo Lin School of Medicine in the National University of Singapore, and Duke-NUS Graduate Medical School, Singapore. E-mail: rathi_mahendran@nuhs.edu.sg.

KEIKO KATAGIRI is an Associate Professor in the Graduate School of Human Development and Environment at Kobe University, Naba-ku, Kobe 657-8501 Japan. E-mail: QZY11242@nifty.com.