Title

Neighbourhood effects on body constitution - A case study of Hong Kong

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Title

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Abstract

Traditional Chinese Medicine (TCM) has long perceived environment as an integral part of the development of body constitution, which is a personal state of health closely related to disease presence. Despite of the ever-growing studies on the clinical effectiveness of TCM and the scientific linking between body constitution and diseases, the geographical influence on body constitution has yet remained an unexplored territory. This study sought to investigate whether the neighbourhood environment is relevant to the composition of body type of a population through statistical multilevel and Geographic Information Systems modelling. The analysis comprised 3,277 participants who had completed their body type assessment between 2009 and 2012 inclusive. The multilevel analysis also took simultaneous accounts of both individual-level (gender, age, BMI, type of housing) and area-level (percent greenery, percent road surface, total road intersection, sky view factor, temperature, relative humidity, rainfall and social deprivation index) characteristics to explain geographical variation by body types. Significant random or place effects ($p<0.001$) were identified in the multilevel models. The spatial variation of body constitution involved the dynamic interplay between individual and environmental factors. The findings amassed the first scientific indications to back the common belief that place does play a role in the development of body constitution and is worthy of further investigation. By considering spatial and personal attributes simultaneously, the study can yield valuable insights into the patterning of area variation in body constitution and disease presence.

Keywords

Hong Kong; Neighbourhood effect; body constitution; multilevel model; Traditional Chinese Medicine (TCM); Geographic Information System (GIS)

INTRODUCTION

Traditional Chinese Medicine (TCM), which has its roots in oriental philosophy and culture, is one of the oldest medical practices with a history of over 2000 years. This holistic medical system has developed through accumulating intelligence from ancient theories (such as the seminal text of TCM titled the "Yellow Emperor's Inner Canon") and daily life experiences, as well as continuous refining and experimenting by generations of practitioners. The complexity of TCM theory and practice has made it one of the most original and controversial scientific achievements of the ancient Chinese civilisation. Contrary to contemporary western medicine (CWM) that emphasizes disease treatment as well as its clinical efficacy, the holistic approach of TCM emphasizes more on disease prevention through the restoration of syndromes (*zheng*) or "pathophysiologic" status (Tsang et al., 2013). The practice of TCM includes a broad spectrum of treatment alternatives such as herbal medicine, tuina, qi gong, moxibustion, acupuncture and dietary therapy. TCM emerges as a complementary and alternative health approach since its integration with CWM in the 1950s, especially among the Chinese-speaking communities in Mainland China, Hong Kong, Taiwan and Singapore (H. J. Chung, 2011; V. C. Chung et al., 2014; Loh, 2009; W. Wong et al., 2014). The integrative approach is widely applied to treat diseases where the "one-drug-fits-all" approach of CWM is not particularly effective, such as allergy, certain types of arthritis, and different types of malignancies (Li et al., 2013; van der Greef et al., 2010; X. Wang et al., 2011b). The integration of TCM and CWM has benefited not only the therapeutic processes of major medical illnesses in terms of efficacy but also in terms of reducing medication requirements and minimizing side effects (Efferth et al., 2007; Ling et al., 2014; J. Liu et al., 2011; Xu et al., 2006).

TCM has long observed personal wellbeing as a dynamic balance between human body and the environment. Body constitution, according to TCM, is an individual's personal state of health expressed in reference to body metabolism and susceptibility to pathogenic factors. The World Health Organisation (WHO, 2007) defines constitution as "… the characteristics of an individual, including structural and functional characteristics, temperament adaptability to environmental changes and susceptibility to diseases. It is relatively stable, being in part, genetically determined and in part, acquired". From the TCM perspective, body constitution is transient in nature and a disease may ensue when the inner harmony of a human body is disrupted in response to the external environment. The concept of body constitution is not exclusively unique to TCM and is synonymous with "prakriti" in Ayuverdic medicine practised in India (Bhushan et al., 2005; Chopra & Doiphode, 2002; Svoboda, 1996). There has been an emergence of various classification theories on individual differences through regularity in human life and health (J. Wang et al., 2011a). Different words such as temperament, personality, build, composition, nature, and constitution have been used by scholars from around the world (Caspi et al., 1997; Do et al., 2012; Hintsanen et al., 2012; Lerner, 1969; Lerner & Korn, 1972; S. H. Park et al., 2011).

Wang Qi proposed in the late 1970s the constitutional theory of TCM, accepted later in 2009 as the national standard of body constitution classification in China (China Association of Chinese Medicine, 2009; Q. Wang, 2005). The English translation of TCM philosophy by Z. Liu (2009) covering the oriental phenomena of Qi, and of Yin-Yang and the Five Elements provides a basic understanding to the physical constitution of body. More recently, J. Wang et al. (2011a) consolidated various research methods used in classifying body constitution, including philology, informatics, epidemiology, and molecular biology.

The constitutional theory establishes nine body types, namely Type A – Balance (Ping He), Type B – Qi Deficiency (Qi Xu), Type C – Yang Deficiency (Yang Xu), Type D – Yin Deficiency (Yin Xu), Type E – Phlegm Dampness (Tan Shi), Type F – Damp Heat (Shi Re), Type G – Blood Stagnation (Xue Yu), Type H – Qi Depression (Qi Yu) and Type I – Special Diathesis (Te Bing). Simply stated, type A is a balanced body constitution and highly valued in health preservation whereas the other eight body types are considered imbalanced or assuming pathological constitutions. It is impossible to describe in detail characteristics of the TCM body constitution. A general summary with illustrative examples for each body type is included in Table 1. Further accounts of the body constitution and its associated diseases are available in Low (2014).

- Insert Table 1 -

The emergence of health geography has established progressive interests of the role of location, space and place in explaining spatial variation in health (Dummer, 2008; R. Kearns & Moon, 2002; R. A. Kearns & Joseph, 1993; Smyth, 2008). The place effect on body constitution is widely recognized in TCM but has largely remained an equivocal statement or anecdotal evidence. The constitutional theory and health geography do overlap at significant points because both fields reckon that the environment or geographical settings have an influence on human health (Q. Wang, 1995). Despite a plethora of literature attributing place effects on health, there remains a shortage of scientific and evidence-based studies linking place effects or environmental factors with TCM body constitution. Discussions on place effects not only have been theoretical and increasingly taken for granted by many TCM researchers but also descriptive and vague in nature (He et al., 1986; Huang, 2001; Xue, 2006). Moreover, these studies did not explicitly “measure” the influence of place of living on body constitution so much so that place effects have remained speculative and a grey area in literature to date. The philosophical differences between TCM and mainstream western medicine make TCM difficult to comprehend and generalise. Furthermore, TCM terminologies often do not have western medicine counterparts and the medical probes are difficult to grasp (Tsang et al., 2013). For example, there is no equivalent anatomical organ or function in western medicine to describe the functional entity of "zang-fu" in TCM that encompasses multiple organs (including heart, liver, spleen, lungs and kidneys).

Present day TCM studies are mainly about clinical efficacy. This study is the first attempt to incorporate health geography and body constitutional theory in investigating the interconnectedness between health and the place of residence. The research hypothesis is that the place of residence has a "neighbourhood effect" on the TCM concept of body constitution. Drawing on precedents from neighbourhood effects research on health (Diez Roux, 2001; Pickett & Pearl, 2001), this study assumed neighbourhoods to be an actual census subdivision at the level of street-block group for hypothesis testing in multilevel analysis. The street-block group is the smallest census tract demarcated by streets and measures an average size of 0.22 km^2 with a minimum of 400 residents (Census and Statistic Department, 2011). It is widely known that the physical environment and social conditions in Hong Kong can vary a great deal within a short distance because of its limited land and high-density vertical development. A street-block is small enough to enclose similar housing types or housing estates to accommodate people of rather similar socio-economic status (Low et al., 2013). This smallest census unit can ensure homogeneity of the neighbourhood unit in terms of reduced environmental and socio-economic variability. The study also employed a Geographic Information System (GIS) and explored cartographic visualisation methods to highlight spatial association between specific environmental factors and body constitution. Given that body constitution can offer signals about the personal state of health and susceptibility to pathogenic factors, an understanding of the relationships between environmental factors and body constitution would contribute to a more proactive, holistic and individualized healthcare.

DATA AND METHOD

Data and study area

The body constitution data in this study came from the Wilson T.S. Wang Centre of Integrated Health Management (CIHM) of the Kwong Wah Hospital, which is the only subsidiary hospital in Hong Kong providing comprehensive TCM integrated services that include an assessment test of body constitution. Ethical approval KW/EX-11-100(42-04)(TCM) has been obtained from the Kowloon West Cluster Clinical Research Ethics Committee to undertake the study. 3,277 voluntary attendees of the CIHM between 2009 and 2012 inclusive consented to participate in the study. As body constitution assessment was conducted on a voluntary and user pay basis (at a nominal rate of HKD200), these study participants were not random and represented individuals who were self-conscious about their health status or suffering from certain illnesses and seeking alternative remedy.

The participants comprised mostly of middle-aged Chinese descendants living within the catchment areas of Kowloon West Cluster, Kowloon Central Cluster and Kowloon East Cluster catchment areas (Figure 1). Taking into consideration of travel cost and time, it is expected that a hospital-based sampling would likely succumb to sampling bias. Despite the exclusive provision of body constitution assessment at the CIHM, our sample showed that there were fewer participants originating from the more distant parts of Hong Kong (e.g., the island districts and peripheral areas). A plot of the sample size show a negative curvilinear function against the Euclidean distance to CIHM (Figure 2a) suggesting that the sample is under-represented in areas located further away from the CIHM. Another curvilinear function shown in Figure 2b uses normalised population (i.e., street-block population against total population of Hong Kong in 2011) as the weighting function for the distance measure, which further exacerbates the sampling bias. The study thus applied an adjustment factor to compensate for under-sampling in certain areas using a log transformation of distance and normalised population (Guagliardo, 2004) to yield an adjusted sample size of 6,294.

- Insert Figures 1 & 2 -

TCM practitioners assessed body constitution of the participants by cross-referencing with a well-established measurement instrument, namely the "Constitution in Chinese Medicine Questionnaire" comprising of 60 items divided into 9 sub-scales (Q. Wang et al., 2006; W. Wong et al., 2013; Zhu et al., 2006; Zhu et al., 2007). The self-administered questionnaire has two parts. The first part covers a set of straightforward and objectives questions concerning personal behaviour, lifestyle and health status. These questions include eating pattern, frequency of exercise, smoking and drinking habits, most disturbing symptoms or illnesses and their influences on daily life, use of western medication, and prior surgery. The second part includes more subjective and symptomatic questions about the general physical wellbeing, the condition associated with urinary and bowel movements, mouth and skin conditions, emotional states, special symptoms (such as allergies, body aching, irregular heartbeats, etc.), sweat disorders, menstruation details (applicable to women), digestive issues, quality of sleep, and conditions associated with face, hair and eyes. A participant may be diagnosed to possess a dominant body constitution or multiple types of (usually two but not more than three) body constitution. The latter is not uncommon because of the transient nature of body constitution, especially for individuals with illnesses. This study assumed that each participant had a type of body constitution or retained the first/primary type in cases of multiple body constitutions.

Method of analysis

Multilevel analysis has been widely applied in health research to enable a systematic analysis of the geographic variation in health. This statistical method is powered to distinguish between area (contextual) effects and individual (compositional) characteristics on personal health phenomenon (Denissen et al., 2008; Diez-Roux et al., 1997; Duncan et al., 1993; Merlo et al., 2012; Muntaner et al., 2011). The present study adopted a multilevel logistic regression model with binary outcome functions (Heck et al. 2012) for the hypothesis testing of the variability of each body constitution by the place of living. As body constitution is not an ordinal or ranked variable and does not have a type that corresponds to a reference category, this study resorted to running separate binary logistic functions instead of using a single multinomial logistic function that compares successive categories to a reference category. The probability of each target body type i (p_i) was tested against other body types (non type i) bundled into a single non-target or reference group. In other words, nine multilevel models were developed in this study in which each body type had its own multilevel model (with dichotomous outcomes of 1=type i and 0=non type i). Conceptually, this approach enables more straightforward, intuitive and meaningful pairwise interpretation of the binary logistic function to predict the probability of each body type (p_i) at the exploratory stage.

The multilevel data structures modelled each body type using two different types of investigational units: (i) the individual level, and (ii) the neighbourhood or street-block group level. After the geocoding process of fixing locations of study participants based on their home addresses, each individual (level-1) was assigned into a street-block group (level-2) according to his/her area of residence. The weighted sample consisting of 6,294 participants nested within 1,065 street-blocks serves two purposes. Firstly, it allows the conversion of point-based data into areal units for multilevel analysis. Secondly, it minimises participant variability in terms of socio-economic characteristics (e.g., housing affordability or income) and environmental conditions (e.g., spaciousness or air quality) (Lai et al., 2013; Low et al., 2013).

Choice of Variables

Two models were developed for the two-level binary logistic functions. The first model (Model 1) tested for significant variance or random effect in the average probability (p*i*) of an individual to have the target body type *i* [Eqn 1]. Here, the variance or random effect is "neighbourhood" or "place" effect of interest to this study (see Blakely and Subramanian (2006).

Logit (p*i*)= log odds= log (p*i* /1- p*i*) = M + EA [Eqn 1]

where

p*i* = probability for the target body type *i*;

M = overall mean probability expressed on the logistic scale;

EA = area residual or random effect at level-2. The area residuals are on logistic scale and normally distributed with a mean of "0" and variance VA; and

VA = area residual variance expressed on the logistic scale (that is, variance around M).

The second model (Model 2) examined if personal or neighbourhood factors at each investigational unit contributed to variation in the body constitution outcome. Three kinds of explanatory variables are available: personal, socio-economic/demographic and environmental/meteorological factors. The personal data came from body constitution assessment at the CIHM, socio-economic/demographic data for 2011 were from the Hong Kong Census and Statistic Department, whereas environmental and meteorological data for the same period were obtained from the Hong Kong Lands Department and Hong Kong Observatory respectively. The study used GIS processing to integrate individual data with exploratory variables through their spatial locations. The individual-level explanatory variables include gender, age, body mass index (BMI), and type of housing (a socio-economic indicator at the individual level, see Low et al. (2013). The area-based explanatory variables include percent greenery, percent road surface, total road intersection, sky view factor (SVF or a measure of urban compactness, see Chen et al. (2012), temperature, relative humidity, rainfall, and social deprivation index (SDI, see C. M. Wong et al. (2008). Table 2 shows a complete list of the 16 input variables used in the development of Model 2. A multicollinearity test conducted among the input variables indicated that none of the variance inflation factors was of sufficient magnitude to suggest a collinearity problem between the explanatory variables; hence, we decided to include all variables into Model 2.

- Insert Table 2 -

Being a pioneer in examining possible linkages between environmental factors and TCM body constitution, there are few or no earlier studies reporting contextual information or a standard set of environmental variables. This study abstracted some contextual indicators associated with human wellbeing and variables commonly used in health geography to bring out plausible explanation. For example, road intersections and road surface areas have served as proxies for human exposure to poor air quality that is potentially hazardous to human health (Friedman, 2001). Percent greenery is a widely used measure to relate the benefits of greenery on human health in an urban setting (Ellaway et al., 2005; Nielsen & Hansen, 2007) whereas SVF is an acceptable indicator to reflect building density and urban heat islands (Chen et al., 2012; Krüger et al., 2011; Lai et al., 2013). Studies have also shown that people living in areas of high social deprivation are more likely from the lowest socioeconomic group and falling victims of unhealthy lifestyles (Balarajan et al., 2011; Ross et al., 2013). Apart from socio-economic and built components of the living environment, meteorological parameters such as temperature, relative humidity and rainfall amount are important variables to consider since a few body constitutions described in Table 1 are susceptible to heat, cold and humidity.

Another research bottleneck concerns a lack of reference regarding absolute or contextual standards for each type of body constitution. For example, the relationships between composite indices, such as SVF and SDI, and each body type are not intuitively obvious. Considering the exploratory nature of this study, it is easier to bring out and highlight the "influence" of these explanatory variables on body constitution by using ordinal categorical measures (such as upper, middle, and lower tertiles). Here, all explanatory variables were set to binary classes (1 = upper tertile and 0 = otherwise) (Witten et al., 2011). The dummy coding of the explanatory variables is also to facilitate subsequent spatial analysis by means of the bivariate choropleth mapping technique described in the next section.

Model 2 hypothesized that the probability of having a body constitution type is influenced by individual (level-1) variables, the area of residence, as well as neighbourhood (level-2) factors [Eqn 2].

Logit (p*i*) = M + ß1 gender + ß2 elderly + ß3 overweight + ß4 public housing [Eqn 2]

+ ß5 greenery + ß6 road intersection + ß7 road surface + ß8 SVF

+ ß9 temperature (summer) + ß10 temperature(winter)

+ ß11 relative humidity (summer) + ß12 relative humidity (winter)

+ ß13 rainfall (summer) + ß14 rainfall (winter) + ß15 SDI

+ ß16 population density + EA

where

ß1…. ß3 = regression coefficients for the personal factors (level-1);

ß4 = regression coefficients for the individual level socio-economic factor (level-1);

ß5…. ß14 = regression coefficients for the area level environmental factors (level-2); and

ß15…ß16 = regression coefficients for the area level socio-demographic factors (level-2).

This study followed the recommended robust standard error estimation procedure (or sandwich estimator) in SPSS 20.0 (Heck & Thomas, 2009; Hox, 2010) in handling possible violation of model assumptions or data departure from normality.

Method of display

Results of the multilevel analysis cannot inform the spatial distribution of a specific body constitution against a selected environmental factor to reveal possible spatial concentration/ clustering or the lack of spatial differentiation. The bivariate choropleth mapping technique allows classification of estimates derived from the multilevel models to visualise the spatial relationships between body constitution and neighbourhood-level factors. A bivariate choropleth map is a representation of two classified themes plotted on the same enumeration units and superimposed on one another to show their spatial agreement or disagreement. To render easy interpretation of a bivariate choropleth map, each theme must have not more than three ordinal groups (representing low, medium, and high values). Superimposing two themes, each with three ordinal groups, yield a composite map of nine possible outcomes (see Figure 3) in which the low-low and high-high combinations reveal spatial agreement whereas the low-high and high-low groupings indicate spatial disagreement. Hence, two types of spatial association (positive/agreement and negative/disagreement) between the two themes are possible. The remaining combinations are variable and usually disregarded for purposes of interpretation (i.e., the respective areas are left blank). The bivariate choropleth mapping technique using the proposed colour scheme can better highlight the spatial variability of a select body constitution by the neighbourhood units.

- Insert Figure 3 -

RESULTS

a) Multilevel analysis

Model 1 provides a means to justify whether a multilevel analysis is necessary by examining the existence of between-group variance. Failing to reject the null hypothesis of “zero or absence of between-group variance” means that a random or place effect is not necessary in the model. The variance component in Table 3 suggests that the estimated variance of the random intercept (with the exception of Type G and Type I) significantly varies among the street-block groups ($p<0.001$). Here, rejecting the null hypothesis justifies the need for developing a multilevel model (Heck & Thomas, 2009). Subsequent analysis of the Intraclass Correlation Coefficient (ICC column in Table 3) of each target body type also shows values ranging between 24 and 31 percent indicating that a reasonable amount of spatial variability of each body type can be attributed to random or neighbourhood effects arising from street-blocks. A larger variance implies a greater variability among the neighbourhoods (Merlo et al., 2005).

- Insert Table 3 -

Personal, socio-economic, socio-demographic, and environmental variables were added as binary explanatory variables to explore spatial variability of street-blocks (i.e., random or place effect) as suggested by model 1. Table 4 shows a detailed account of the estimates and explanatory analysis of Model 2 for each target body type, highlighting variables showing a statistically significant relationship ($p<0.05$). Type A, which is the only balanced body constitution among all other types, emerged as the only body type exhibiting a negative relationship with public rental housing. This result suggests that participants living in public rental housing are less likely to possess Type A body constitution. A possible explanation is that people of higher socio-economic profiles (i.e., non-public rental housing residents) might have better living conditions or healthier lifestyles that increased their likelihood of developing a balanced body constitution. By and large, the results in Table 4 show that personal factors outperformed socio-demographic, socio-economic, and environmental factors in determining or influencing body constitution. Indeed, the variation in body constitution by area of residence (except for Types G and I) was found more closely tied to personal factors such as differences in gender, age, and BMI.

- Insert Table 4 -

Table 5 shows the percentage of participants correctly identified as having a particular body type (or true positives) by the different models. Model 1 did not include any explanatory variables whereas Model 2 included personal, socio-economic/demographic, and environmental explanatory variables. A model's sensitivity in prediction generally improves with the addition of explanatory variables as evident from results of this study, although quite minimal in most cases. This observation may imply the following disposition: (i) that the set of explanatory variables may not be appropriate or suitable in the context of body constitution; (ii) that the phenomenon of body constitution is extremely complicated and involving many explanatory variables not covered in the present framework; and (iii) that both of the above situations are true.

- Insert Table 5 -

b) Bivariate choropleth mapping

Table 4 shows that Type B is the only body type exhibiting significant relationships with environmental variables. Type B correlated positively to *Road Surface* and negatively to *Temperature (winter)* but the multilevel analysis cannot inform spatial heterogeneity, that is, which specific street-block groups have more or less of a specific body constitution with respect to the neighbourhood-level environmental factors. The spatial variability of body constitution and environmental factors, in this case, is visualised using the bivariate choropleth mapping technique as shown in Figure 4.

- Insert Figure 4 -

The bivariate choropleth map in Figure 4a displays a positive spatial association between Type B and *Road Surface* at the street-block level. Street-blocks coloured in blue indicate both Type B outcomes (percent of participant population by street-blocks) and *Road Surface* (percent of street-block areas) are in the upper tertile. Similarly, street-blocks coloured in orange indicate both Type B outcomes and *Road Surface* are in the lower tertile. These street-blocks (coloured in blue or orange) show locations where the body constitution and environmental factor are in direct agreement with the multilevel Model 2. Despite a substantial number of street-blocks in disagreement (coloured in black), the West Kowloon area has more street-blocks coloured in blue compared to the rest of neighbourhoods in Hong Kong. This observation about a high incidence of Type B body constitution in street-blocks with a high percentage of paved *Road Surface* in West Kowloon signifies possible local environmental association with body constitution. The observation is supported by the pie charts in Figure 4a showing that the proportion of blue to orange for the general population is 1:2 whereas that for West Kowloon is 2:1. The pie charts in conjunction with the bivariate choropleth map highlight that residents in specific street-blocks in West Kowloon have a higher propensity of developing Type B body constitution because of specific characteristics of the built environment (i.e., road surface coverage) and other personal factors.

Likewise, the bivariate choropleth map in Figure 4b displays a negative spatial association between Type B and *Temperature (winter)* at the street-block level. The mapped results clearly split the Kowloon area into West and East Kowloon. West Kowloon appears to have a high concentration of street-blocks coloured in yellow indicating lower outcomes of Type B (lower tertile) are associated with higher winter temperatures (upper tertile). On the contrary, East Kowloon is populated by street-blocks showing the opposite trend with a high concentration of street-blocks coloured in red suggesting higher outcomes of Type B (upper tertile) are associated with lower winter temperatures (lower tertile). The spatial separation observed in Figure 4b suggests that a higher concentration of Type B body constitution may be linked with winter temperatures at the geographical locations, along with other personal factors. Interestingly and because of the binary construct of the multilevel models, Figures 4a and 4b yield mutually exclusive results that aid the interpretation of dominant place effects by geographic locations.

DISCUSSION

This study sought to investigate whether a geographic location can exert its neighbourhood effect to influence body constitution. Our findings revealed that spatial variability of body constitution was evident within a small and compact city like Hong Kong. The results implied that the likelihood of having the same body constitution for individuals living in the same neighbourhood was more similar compared to those individuals living in other neighbourhoods ($p>0.001$ for all body types except G and I). Past literature has often generalised body constitution between populations by a broad and ambiguous setting within China (such as Northern versus Southern China) because of their very distinctive difference in climate, geography and culture. This study not only has demonstrated the merits of studying the distribution of body constitution at a micro scale but also heightened the importance of geographical aspect in analysing variability from an ecological perspective, as shown in Figures 4a and 4b. The identification of place effects on body constitution has shed lights on the methodological aspect in examining the impact of the environment on health. In particular, the study has confirmed the feasibility of investigating the spatial variability of body constitution, an "anatomic" classification difficult to clarify based on reductionism, through geoprocessing (i.e. data encoding, address geocoding, aggregating into geographical units, and conducting spatial analysis by means of GIS operation). The research has served as an exemplary study that integrates GIS methodology and the multilevel modelling approach in understanding the significance of place effects on body constitution.

The study also demonstrates the complex and "multifactorial" nature of the TCM concept of body constitution as reflected through the multilevel modelling approach. The variance or random effects underlying the street-block groups have suggested many interacting factors behind the body type outcome needed to be accounted for, whether of personal or neighbourhood contextual differences. This study reveals that individual-level or personal factors have more explanatory powers than either socio-economic or neighbourhood contextual factors or their combination in impacting body constitution. Personal characteristics such as gender, age, and BMI were found statistically significant with almost all types of body constitution ($p<0.05$). At the same time, the multilevel models also showed that a participant's socio-economic status, as reflected through the housing status, was indicative of a certain type of body constitution. The research suggests that the influencing factors on body constitution are beyond the individuals. Specifically, environmental attributes at the street-block level (such as road surface coverage and average winter temperature) were found statistically significant for Type B body constitution ($p<0.05$). The findings imply that body constitution is a phenomenon involving a complex interplay among many factors and a single indicator, or even a list of "accepted" indicators as demonstrated in this study, may not fully explain its outcome.

This research has made a first attempt to visualise and highlight the spatial dimension of the multilevel modelling approach through bivariate choropleth mapping technique. The availability of various analytical and display functions in a GIS has facilitated visual exploration of the spatial correlation between environmental indicators and body constitution. A well-designed colour scheme for the bivariate choropleth mapping can highlight noticeable differences in the spatial distributional pattern to suggest possible environmental association with body constitution (see Figures 4a and 4b). This study has illuminated the role of exploratory spatial data analysis in gaining a better understanding of a health phenomenon like body constitution and merits further investigation.

LIMITATIONS AND CONCLUSIONS

The authors acknowledge that there are inherent limitations and technical constraints to be addressed in future research. The findings of this study were based on relatively unsophisticated models that were more exploratory than confirmatory in nature. Besides, the study examined neighbourhood effects using only physical environmental characteristics quantifiable using a GIS. There was also an insufficient number of personal and socio-economic attributes (such as income, educational attainment and occupation) to enable more comprehensive inference on body constitution (Dragano et al., 2007; Kennedy et al., 1998). Moreover, the neighbourhood effects on body constitution did not account for the length of residency or the place of work or school (Labriola et al., 2006; Y. Park et al., 2008) due to a lack of such data. At the conceptual level, the spatial analysis of body constitution in this study was subject to the problems of modifiable areal unit (Openshaw, 1984) and uncertain geographic context (Kwan, 2012). These two issues, as encountered in many other health geography studies, are still being actively debated in literature and remained unresolved. Given that the concept of place in relation to body constitution is an unexplored territory, the actual spatial unit to capture an individual's "true geographic context" about the phenomenon deserves further extensive investigation.

However, this study is the first of its kind that infuses the principles of health geography and the GIS methodology to explore the TCM concept of body constitution. The findings offer new methodological insights towards associating place effects on a complicated health outcome differentiated by body constitution that is worthy of continued and robust inquiry. This study has further demonstrated an evidence-based approach in the systematic analysis of geographic variability of body constitution that reveals the dynamic interplay between individual and environmental factors arising from neighbourhoods. Despite various limitations, this research has furnished a benchmark study to characterise the spatial aspect of body constitution through the synergy between GIS technology and statistical analysis. By applying scientific techniques simultaneously with traditional wisdom, this study has brought together the theories of space and place in formalising knowledge about body constitution, which has been prevented so far from being scientifically and systematically explored.

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Table captions

1 Characteristics of body types according to Traditional Chinese Medicine

2 Explanatory variables at each level of the multilevel analysis

3 Multilevel analysis for Model 1: Fixed and random effects

4 Multilevel analysis for Model 2 (Note: Highlighted rows show significant variables for model 2 by each body type.)

5 Model sensitivity

Figure captions

1 Distribution of study participants in Hong Kong

2 Plots of curvilinear functions between the number of participants versus (a) Euclidean distance to the Centre of Integrated Health Management (CIHM) and (b) population-weighted distance to the CIHM. The population weight or normalised population is estimated by taking street block population divided by the total population of Hong Kong in 2011.

3 A graphic illustration of the bivariate choropleth mapping technique and its colour schemes

4 Bivariate choropleth maps showing Type B body constitution and its association with environmental factors: (a) *Road Surface*, and (b) *Average Temperature (winter)*

Table 1 Characteristics of body types according to Traditional Chinese Medicine

Body Type	**Characteristics**
A	A fit and energetic body with glowing appearance (ruddy complexion) and resilience; people of strong capacity for environmental adaptation.
B	People with insufficient Qi (a source of strength and vitality) that yields weak and thin pulse patterns; decreased viscera functions can lead to impaired resilience and low adaptability to excessively hot, cold and windy weather conditions, as well as prolonged recovery from illness.
C	A pathological state caused by a lack of Yang-Qi (陽氣); characterized by decreased metabolic activities, reduced body reactions, aversion to low temperatures, and chills in extremities.
D	Yin Deficiency is associated with dryness within the body, irritability, and vulnerability to heat; being a counterbalance to yang, yin deficiency means an excess of Yang-Qi, resulting in hyperactivity and rising interior heat.
E	Most evident in people with adiposity and those who adopt unhealthy lifestyles and eating habits; increased risk of diabetes, stroke, high blood pressure and cardiovascular diseases.
F	People suffering from internal dampness and heat causing low tolerance to humidity and high temperatures; tendency to be more temperamental and impatient.
G	A pathological state of abnormally viscous blood leading to stagnation, extravasations, and generally sluggish circulation; vulnerability to cold and windy weather conditions, especially among women and the elderly.
H	People suffering from long-term depression and Qi stagnation; Qi depression can lead to unstable moods, special emotional sensitivity and melancholy.
I	A special body type caused by congenital constitutional weakness; people of weak environmental adaptability.

Table 2 Explanatory variables at each level of the multilevel analysis

Category	Name	Description	Values
Level-1			
i) personal	*Gender*	Female vs. male	1= female 0= male
	Elderly	Elderly (65 and over) vs. non elderly	1= elderly 0= non-elderly
	Overweight	BMI of 25or more considered as overweight	1= overweight 0= underweight
ii) socio-economic	*Public Housing*	public rental housing vs. non-public rental housing tenant	1= public rental housing tenant 0= other housing tenant
Level-2			
i) environmental	*Greenery*	The percent greenery by using the upper tertile as cutoff.	1 = High % greenery 0 = Low % greenery
	Road Intersection	Normalised count of road intersection by street-block area, using the upper tertile as cutoff. For 800m-radius buffer neighbourhood, the crude count of road intersection was used.	1 = High road intersection 0 = Low road intersection
	Road Surface	The percent road surface area by using the upper tertile as cutoff.	1 = High % road surface 0 = Low % road surface
	SVF	SVF by using the upper tertile as cutoff	1 = High SVF 0 = Low SVF
	Temperature (summer)	Average monthly temperature from July to September	1 = High temperature 0 = Low temperature
	Temperature (winter)	Average monthly temperature from December to February	1 = High temperature 0 = Low temperature
	Relative Humidity (summer)	Average monthly relative humidity from July to September	1 = High relative humidity 0 = Low relative humidity
	Relative Humidity (winter)	Average monthly relative humidity from December to February	1 = High relative humidity 0 = Low relative humidity
	Rainfall (summer)	Average monthly total rainfall from July to September	1 = High rainfall 0 = Low rainfall
	Rainfall (winter)	Average monthly total rainfall December to February	1 = High rainfall 0 = Low rainfall
ii) socio-demographic	*SDI*	Social deprivation index by using the upper tertile as cutoff	1= High SDI 0= Low SDI
	Population Density	Population density by using the upper tertile as cutoff	1= High SDI 0= Low SDI

Table 3 Multilevel analysis for Model 1: Fixed and random effects

Body Type *(Weighted cases)*	Model 1: Fixed Effect				Model 1: Random Effect				
	log odds (β)	**SE**	**t**	**Odds ratio = Exp(log odds)**	**Estimated variance** (VA)	**SE**	**Z**	**Total variance** *(V_A + 3.29)*	**ICC (%)** *[V_A / (V_A + V_1)]*
A** *(441)*	-2.839	0.075	-37.993	0.058	1.478	0.176	8.389	4.768	31
B** *(1720)*	-1.040	0.047	-22.086	0.353	0.899	0.103	8.742	4.189	21
C** *(558)*	-2.565	0.069	-37.259	0.077	1.388	0.164	8.462	4.678	30
D** *(398)*	-2.879	0.076	-37.955	0.056	1.512	0.188	8.062	4.802	31
E** *(1198)*	-1.567	0.050	-31.455	0.209	0.838	0.108	7.753	4.128	20
F** *(830)*	-2.070	0.061	-34.191	0.126	1.264	0.145	8.749	4.554	28
G** *(183)*	-3.043	0.060	-50.317	0.048	-	-	-	-	-
H** *(873)*	-1.989	0.057	-34.826	0.137	1.065	0.133	8.001	4.355	24
I** *(93)*	-3.267	0.067	-48.746	0.038	-	-	-	-	-

** *$p<0.001$*

Table **4:** Multilevel analysis for Model 2 (Note: Highlighted rows show significant variables for model 2 by each body type.)

Model 2: Body type A

	Coefficient	SE	t	Sig.	Odds Ratio	95% CI for Exp (Coefficient)
Fixed effect						
Intercept	-2.024	0.214	-9.467	0.000	0.132	(0.087, 0.201)
Personal						
Gender	-0.516	0.166	-3.103	0.002	0.597	(0.431, 0.827)
Elderly	0.340	0.261	1.302	0.193	1.406	(0.842, 2.347)
Overweight	-0.848	0.185	-4.592	0.000	0.428	(0.298, 0.615)
Socio-economic/ demographic						
Public Housing	-0.479	0.215	-2.231	0.026	0.619	(0.407, 0.944)
SDI	-0.046	0.178	-0.258	0.796	0.955	(0.674, 1.353)
Population density	0.104	0.183	0.566	0.571	1.109	(0.775, 1.589)
Environment						
Greenery	-0.011	0.196	-0.057	0.955	0.989	(0.674, 1.451)
Road Intersection	0.202	1.179	0.171	0.864	1.224	(0.121, 12.351)
Road Surface	-0.255	0.175	-1.460	0.144	0.775	(0.550, 1.092)
SVF	-0.088	0.178	-0.497	0.619	0.915	(0.646, 1.297)
Temperature (summer)	-0.220	0.208	-1.062	0.288	0.802	(0.534, 1.205)
Temperature (winter)	0.124	0.190	0.652	0.514	1.132	(0.780, 1.641)
Relative Humidity (summer)	-0.327	0.261	-1.249	0.212	0.721	(0.432, 1.204)
Relative Humidity (winter)	-0.036	0.245	-0.146	0.884	0.965	(0.597, 1.559)
Rainfall (summer)	0.169	0.210	0.805	0.421	1.184	(0.785, 1.786)
Rainfall (winter)	-0.009	0.182	-0.052	0.959	0.991	(0.694, 1.414)
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Coefficient**
Random effect						
Level 1 (scale factor)	1					
Intercept (level 2)	1.510	0.183	8.260	0.000		(1.191, 1.914)

Model 2: Body type B

	Coefficient	SE	t	Sig.	Odds Ratio	95% CI for Exp (Coefficient)
Fixed effect						
Intercept	-1.412	0.145	-9.752	0.000	0.244	(0.183, 0.324)
Personal						
Gender	0.352	0.108	3.248	0.001	1.421	(1.15, 1.757)
Elderly	0.118	0.179	0.663	0.508	1.126	(0.793, 1.598)
Overweight	-0.677	0.103	-6.572	0.000	0.508	(0.415, 0.622)
Socio-economic/ demographic						
Public Housing	0.187	0.138	1.353	0.176	1.206	(0.919, 1.581)
SDI	0.169	0.108	1.562	0.118	1.184	(0.958, 1.462)
Population density	0.064	0.112	0.571	0.568	1.066	(0.856, 1.326)
Environment						
Greenery	0.136	0.114	1.196	0.232	1.146	(0.917, 1.432)
Road Intersection	-0.191	0.686	-0.279	0.780	0.826	(0.215, 3.168)
Road Surface	0.351	0.108	3.254	0.001	1.421	(1.150, 1.755)
SVF	0.142	0.106	1.334	0.182	1.153	(0.935, 1.420)
Temperature (summer)	0.216	0.132	1.636	0.102	1.241	(0.958, 1.606)
Temperature (winter)	-0.277	0.124	-2.245	0.025	0.758	(0.595, 0.965)
Relative Humidity (summer)	0.221	0.160	1.382	0.167	1.248	(0.912, 1.708)
Relative Humidity (winter)	-0.272	0.154	-1.768	0.077	0.762	(0.564, 1.030)
Rainfall (summer)	-0.135	0.125	-1.084	0.278	0.874	(0.684, 1.115)
Rainfall (winter)	0.076	0.117	0.652	0.515	1.079	(0.858, 1.356)
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Coefficient**
Random effect						
Level 1 (scale factor)	1					
Intercept (level 2)	0.897	0.104	8.598	0.000		(0.714, 1.127)

Model 2: Body type C	Coefficient	SE	t	Sig.	Odds Ratio	95% CI for Exp (Coefficient)
Fixed effect						
Intercept	-2.525	0.209	-12.081	0.000	0.080	(0.053, 0.121)
Personal						
Gender	0.093	0.150	0.620	0.535	1.097	(0.818, 1.472)
Elderly	0.932	0.223	4.174	0.000	2.540	(1.639, 3.934)
Overweight	-0.976	0.170	-5.736	0.000	0.377	(0.207, 0.526)
Socio-economic/ demographic						
Public Housing	-0.024	0.193	-0.123	0.902	0.977	(0.668, 1.427)
SDI	-0.269	0.168	-1.597	0.110	0.764	(0.550, 1.063)
Population density	0.137	0.185	0.742	0.458	1.147	(0.798, 1.649)
Environment						
Greenery	0.060	0.174	0.347	0.729	1.062	(0.755, 1.494)
Road Intersection	0.161	1.086	0.149	0.882	1.175	(0.140, 9.876)
Road Surface	-0.178	0.165	-1.080	0.280	0.837	(0.606, 1.156)
SVF	0.020	0.166	0.121	0.904	1.020	(0.736, 1.414)
Temperature (summer)	-0.296	0.213	-1.389	0.165	0.743	(0.489, 1.13)
Temperature (winter)	0.351	0.202	1.739	0.082	1.420	(0.956, 2.108)
Relative Humidity (summer)	-0.164	0.227	-0.724	0.469	0.849	(0.544, 1.323)
Relative Humidity (winter)	0.346	0.215	1.611	0.107	1.413	(0.928, 2.152)
Rainfall (summer)	0.201	0.200	1.004	0.315	1.222	(0.826, 1.808)
Rainfall (winter)	-0.118	0.183	-0.645	0.519	0.889	(0.621, 1.271)
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Coefficient**
Random effect						
Level 1 (scale factor)	1					
Intercept (level 2)	1.559	0.184	8.492	0.000		(1,238, 1.964)

Model 2: Body type D	Coefficient	SE	t	Sig.	Odds Ratio	95% CI for Exp (Coefficient)
Fixed effect						
Intercept	-3.108	0.270	-11.501	0.000	0.045	(0.026, 0.076)
Personal						
Gender	0.694	0.213	3.257	0.001	2.001	(1.318, 3.037)
Elderly	0.194	0.294	0.660	0.509	1.215	(0.682, 2.164)
Overweight	-1.369	0.226	-6.064	0.000	0.254	(0.163, 0.396)
Socio-economic/ demographic						
Public Housing	-0.072	0.228	-0.315	0.753	0.931	(0.596, 1.454)
SDI	-0.177	0.192	-0.919	0.358	0.838	(0.575, 1.221)
Population density	-0.118	0.194	-0.610	0.542	0.889	(0.608, 1.299)
Environment						
Greenery	0.091	0.193	0.470	0.638	1.095	(0.750, 1.599)
Road Intersection	0.219	0.949	0.230	0.818	1.244	(0.194, 8.000)
Road Surface	-0.101	0.180	-0.559	0.577	0.904	(0.635, 1.287)
SVF	-0.013	0.176	-0.076	0.940	0.987	(0.699, 1.393)
Temperature (summer)	-0.102	0.226	-0.452	0.651	0.903	(0.580, 1.406)
Temperature (winter)	0.352	0.218	1.615	0.106	1.421	(0.928, 2.178)
Relative Humidity (summer)	0.314	0.279	1.127	0.260	1.369	(0.793, 2.364)
Relative Humidity (winter)	-0.235	0.265	-0.887	0.375	0.790	(0.470, 1.329)
Rainfall (summer)	0.054	0.205	0.261	0.794	1.055	(0.705, 1.578)
Rainfall (winter)	-0.188	0.185	-1.103	0.311	0.829	(0.576, 1.192)
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Coefficient**
Random effect						
Level 1 (scale factor)	1					
Intercept (level 2)	1.716	0.209	8.194	0.000		(1.351, 2.180)

Model 2: Body type E						
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Exp (Coefficient)**
Fixed effect						
Intercept	-2.390	0.178	-13.396	0.000	0.092	(0.065, 0.13)
Personal						
Gender	-0.067	0.121	-0.556	0.578	0.935	(0.737, 1.186)
Elderly	-0.425	0.207	-2.049	0.040	0.654	(0.436, 0.982)
Overweight	2.137	0.117	18.272	0.000	8.473	(6.737, 10.656)
Socio-economic/ demographic						
Public Housing	-0.278	0.162	-1.715	0.086	0.757	(0.551, 1.041)
SDI	-0.025	0.134	-0.183	0.855	0.976	(0.750, 1.270)
Population density	0.049	0.134	0.362	0.717	1.050	(0.807, 1.366)
Environment						
Greenery	-0.272	0.143	-1.907	0.057	0.762	(0.576, 1.008)
Road Intersection	0.626	0.882	0.710	0.478	1.870	(0.332, 10.538)
Road Surface	-0.154	0.128	-1.203	0.229	0.858	(0.668, 1.102)
SVF	0.008	0.127	0.065	0.948	1.008	(0.786, 1.293)
Temperature (summer)	0.230	0.164	1.400	0.161	1.259	(0.912, 1.737)
Temperature (winter)	-0.171	0.154	-1.109	0.267	0.843	(0.624, 1.140)
Relative Humidity (summer)	0.130	0.180	0.723	0.470	1.139	(0.801, 1.619)
Relative Humidity (winter)	0.021	0.178	0.121	0.904	1.022	(0.721, 1.447)
Rainfall (summer)	0.045	0.150	0.299	0.765	1.046	(0.779, 1.403)
Rainfall (winter)	-0.006	0.139	-0.040	0.968	0.994	(0.758, 1.305)
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Coefficient**
Random effect						
Level 1 (scale factor)	1					
Intercept (level 2)	1.090	0.135	8.053	0.000		(0.854, 1.390)

Model 2: Body type F						
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Exp (Coefficient)**
Fixed effect						
Intercept	-1.617	0.183	-8.827	0.000	0.199	(0.139, 0.284)
Personal						
Gender	-1.004	0.138	-7.263	0.000	0.367	(0.280, 0.481)
Elderly	-0.563	0.270	-2.088	0.037	0.570	(0.336, 0.966)
Overweight	0.581	0.117	4.971	0.000	1.787	(1.421, 2.247)
Socio-economic/ demographic						
Public Housing	0.241	0.178	1.358	0.174	1.273	(0.899, 1.803)
SDI	0.078	0.148	0.524	0.600	1.081	(0.809, 1.444)
Population density	-0.099	0.160	-0.620	0.535	0.906	(0.662, 1.239)
Environment						
Greenery	0.090	0.150	0.600	0.548	1.094	(0.816, 1.468)
Road Intersection	-0.487	0.942	-0.517	0.606	0.615	(0.097, 3.897)
Road Surface	0.085	0.142	0.596	0.551	1.089	(0.824, 1.439)
SVF	-0.103	0.142	-0.723	0.470	0.902	(0.683, 1.192)
Temperature (summer)	-0.355	0.183	-1.935	0.053	0.701	(0.490, 1.005)
Temperature (winter)	0.113	0.166	0.679	0.497	1.120	(0.808, 1.551)
Relative Humidity (summer)	-0.418	0.217	-1.926	0.054	0.658	(0.403, 1.008)
Relative Humidity (winter)	0.313	0.201	1.554	0.120	1.368	(0.921, 2.03)
Rainfall (summer)	0.172	0.179	0.961	0.337	1.188	(0.836, 1.687)
Rainfall (winter)	-0.045	0.159	-0.286	0.775	0.956	(0.700, 1.305)
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Coefficient**
Random effect						
Level 1 (scale factor)	1					
Intercept (level 2)	1.385	0.158	8.779	0.000		(1.108, 1.731)

Model 2: Body type G

	Coefficient	SE	t	Sig.	Odds Ratio	95% CI for Exp (Coefficient)
Fixed effect						
Intercept	-3.020	0.188	-16.042	0.000	0.049	(0.034, 0.071)
Personal						
Gender	0.233	0.149	1.564	0.118	1.262	(0.943, 1.691)
Elderly	0.291	0.252	1.156	0.248	1.338	(0.816, 2.193)
Overweight	-0.158	0.143	-1.107	0.268	0.853	(0.645, 1.130)
Socio-economic/ demographic						
Public Housing	-0.090	0.174	-0.515	0.606	0.914	(0.650, 1.286)
SDI	0.028	0.170	0.164	0.870	1.028	(0.737, 1.435)
Population density	-0.106	0.172	-0.616	0.538	0.899	(0.642, 1.260)
Environment						
Greenery	-0.127	0.164	-0.774	0.439	0.881	(0.639, 1.215)
Road Intersection	-0.431	0.177	-2.434	0.015	0.650	(0.459, 0.920)
Road Surface	-0.142	0.158	-0.900	0.368	0.867	(0.637, 1.182)
SVF	-0.037	0.150	-0.248	0.804	0.964	(0.719, 1.292)
Temperature (summer)	-0.024	0.197	-0.120	0.905	0.977	(0.663, 1.438)
Temperature (winter)	-0.179	0.177	-1.009	0.313	0.836	(0.591, 1.183)
Relative Humidity (summer)	0.052	0.239	0.218	0.828	1.053	(0.66, 1.682)
Relative Humidity (winter)	-0.115	0.235	-0.488	0.625	0.892	(0.563, 1.413)
Rainfall (summer)	-0.042	0.210	-0.201	0.840	0.959	(0.636, 1.446)
Rainfall (winter)	0.237	0.188	1.262	0.207	1.267	(0.877, 1.830)
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Coefficient**
Random effect						
Level 1 (scale factor)	1					
Intercept (level 2)	0.000					

Model 2: Body type H

	Coefficient	SE	t	Sig.	Odds Ratio	95% CI for Exp (Coefficient)
Fixed effect						
Intercept	-2.284	0.186	-12.314	0.000	0.102	(0.071, 0.147)
Personal						
Gender	0.518	0.143	3.627	0.000	1.678	(1.269, 2.220)
Elderly	-0.489	0.223	-2.195	0.028	0.613	(0.396, 0.949)
Overweight	-0.866	0.148	-5.841	0.000	0.421	(0.315, 0.563)
Socio-economic/ demographic						
Public Housing	0.143	0.139	1.025	0.306	1.154	(0.878, 1.516)
SDI	0.069	0.132	0.526	0.599	1.072	(0.828, 1.516)
Population density	-0.030	0.142	-0.212	0.832	0.970	(0.734, 1.283)
Environment						
Greenery	0.125	0.148	0.847	0.397	1.133	(0.848, 1.515)
Road Intersection	0.241	0.794	0.303	0.762	1.272	(0.268, 6.037)
Road Surface	0.061	0.132	0.457	0.648	1.062	(0.819, 1.378)
SVF	-0.106	0.134	-0.789	0.430	0.900	(0.692, 1.170)
Temperature (summer)	0.036	0.164	0.221	0.825	1.037	(0.752, 1.430)
Temperature (winter)	0.180	0.147	1.229	0.219	1.197	(0.898, 1.596)
Relative Humidity (summer)	-0.211	0.194	-1.085	0.278	0.810	(0.554, 1.185)
Relative Humidity (winter)	0.152	0.185	0.820	0.412	1.164	(0.810, 1.672)
Rainfall (summer)	0.086	0.154	0.559	0.576	1.090	(0.806, 1.475)
Rainfall (winter)	-0.069	0.140	-0.497	0.619	0.933	(0.710, 1.227)
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Coefficient**
Random effect						
Level 1 (scale factor)	1.104	0.139	7.948	0.000		(0.863, 1.412)
Intercept (level 2)						

Model 2: Body type I

	Coefficient	SE	t	Sig.	Odds Ratio	95% CI for Exp (Coefficient)
Fixed effect						
Intercept	-3.069	0.174	-17.615	0.000	0.046	(0.033, 0.065)
Personal						
Gender	-0.076	0.144	-0.532	0.595	0.926	(0.699, 1.228)
Elderly	-0.136	0.212	-0.643	0.520	0.873	(0.576, 1.321)
Overweight	-0.135	0.117	-1.153	0.249	0.874	(0.695, 1.099)
Socio-economic/ demographic						
Public Housing	-0.145	0.127	-1.141	0.254	0.865	(0.675, 1.109)
SDI	0.029	0.140	0.205	0.837	1.029	(0.782, 1.354)
Population density	-0.134	0.132	-1.012	0.312	0.875	(0.675, 1.134)
Environment						
Greenery	-0.062	0.137	-0.451	0.652	0.940	(0.718, 1.23)
Road Intersection	-0.211	0.142	-1.479	0.139	0.810	(0.613, 1.071)
Road Surface	0.044	0.150	0.292	0.771	1.045	(0.778, 1.402)
SVF	-0.020	0.132	-0.151	0.880	0.980	(0.757, 1.269)
Temperature (summer)	0.131	0.170	0.773	0.439	1.140	(0.818, 1.59)
Temperature (winter)	-0.067	0.144	-0.464	0.642	0.935	(0.706, 1.24)
Relative Humidity (summer)	0.071	0.208	0.339	0.734	1.073	(0.714, 1.613)
Relative Humidity (winter)	-0.021	0.195	-0.107	0.915	0.979	(0.669, 1.434)
Rainfall (summer)	-0.170	0.170	-0.966	0.319	0.844	(0.604, 1.178)
Rainfall (winter)	0.034	0.144	0.240	0.810	1.035	(0.781, 1.372)
	Coefficient	**SE**	**t**	**Sig.**	**Odds Ratio**	**95% CI for Coefficient**
Random effect						
Level 1 (scale factor)	1					
Intercept (level 2)	0.000					

Table 5 Model sensitivity

Body Type	Model 1	Model 2
A	1.4	2.7
B	11	20.4
C	0	2.9
D	1	1.8
E	2	39.4
F	1	11
G	-	-
H	1.4	1.4
I	-	-

Model 1: Intercept only model

Model 2: Model with explanatory variables (aggregated by street-block)

Note that Type B, Type E and Type F had the most noticeable increases in model sensitivity after adding explanatory variables in Model 2. The increases were mostly attributed to personal attributes (e.g. overweight).

Abbreviations

BMI	Body mass index
CIHM	Centre of Integrated Health Management
CWM	Contemporary western medicine
GIS	Geographic Information System
ICC	Intraclass Correlation Coefficient
SDI	Social deprivation index
SVF	Sky view factor
TCM	Traditional Chinese Medicine

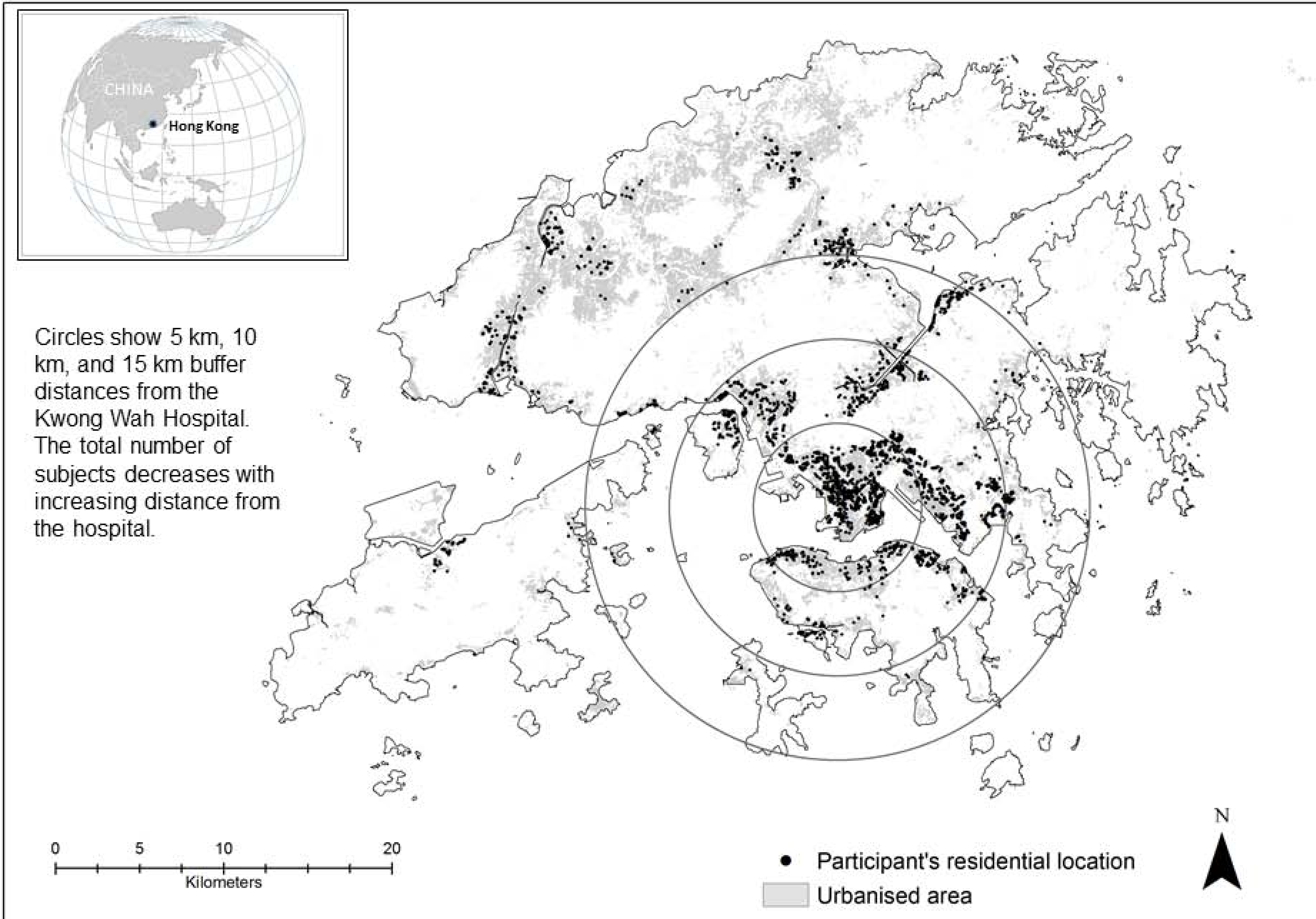
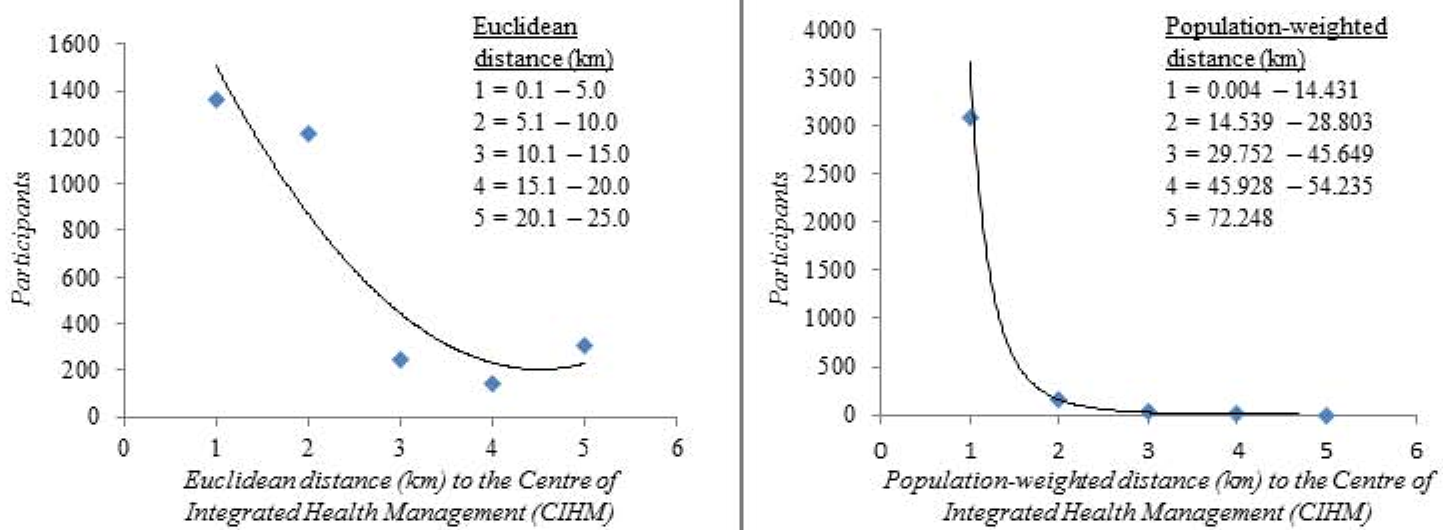


Figure 1 Distribution of study participants in Hong Kong



(a) Number of participants by Euclidean distance

(b) Number of participants by population-weighted distance

Figure 2 Plots of curvilinear functions between the number of participants versus (a) Euclidean distance to the Centre of Integrated Health Management (CIHM) and (b) population weighted distance to the CIHM. The population weight or normalised population is estimated by taking street block population divided by the total population of Hong Kong in 2011.

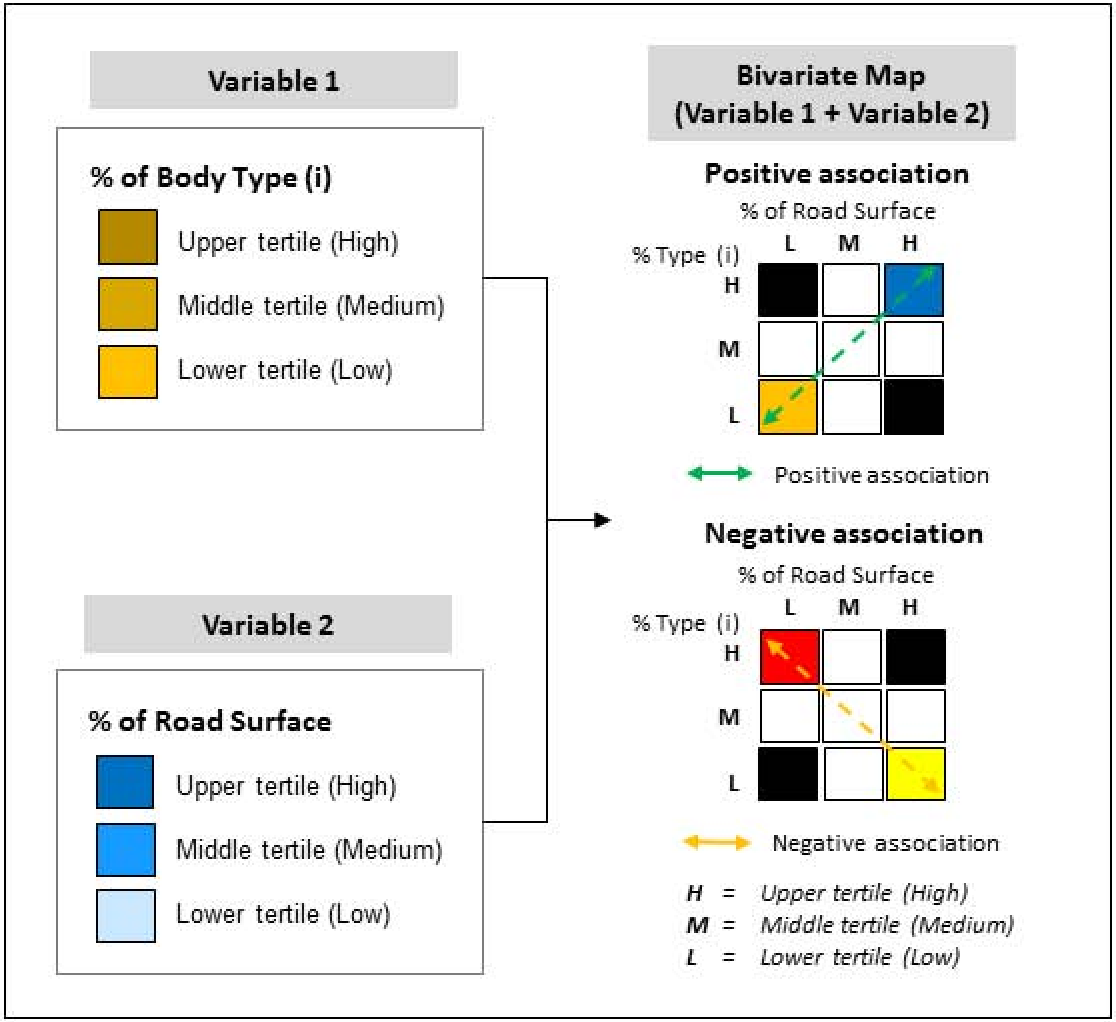


Figure 3 A graphic illustration of the bivariate choropleth mapping technique and its colour schemes

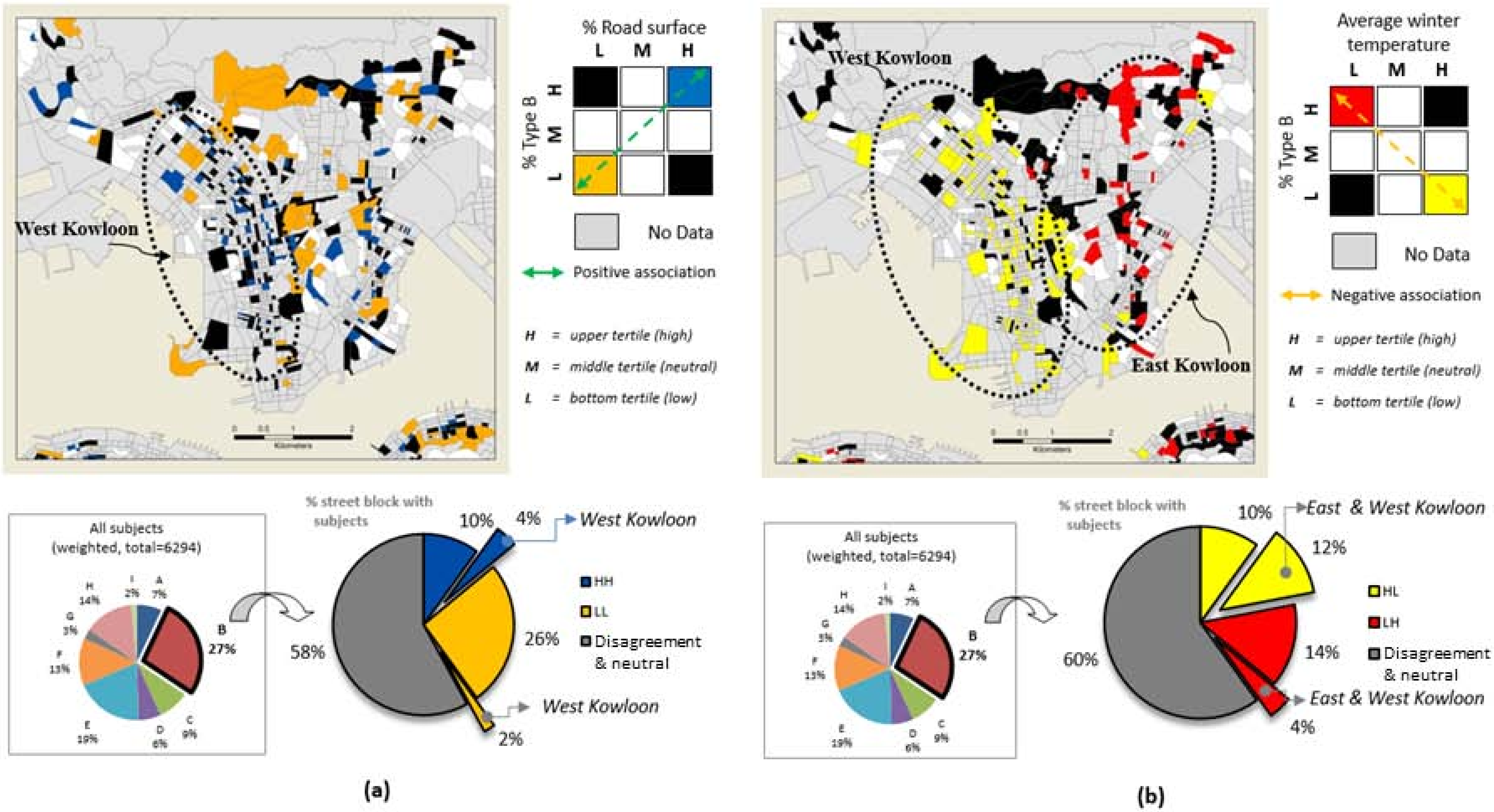


Figure 4 Bivariate choropleth maps showing Type B body constitution and its association with environmental factors: (a) *Road Surface*, and (b) *Average Temperature (winter)*