URBAN FORMS AND HEALTH PROMOTION: AN EVALUATION BASED ON HEALTH-RELATED QOL INDICATORS

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ABSTRACT

Benefits of promoting compact cities have been examined from various angles and in various countries/cities. This study provides additional evidence from the perspective of health promotion in the context of Japanese cities. Different from existing studies, this study adopts a more general concept of health-related QOL, which includes not only physical aspects, but also mental and social aspects. First, we conducted a web-based questionnaire survey, which consists of 36 health-related QOL indicators and their influencing factors, including healthy habits, health activities, and activity-travel behavior, and living environment, etc. The survey was implemented in 2010 and 1,172 valid samples various types of Japanese cities were collected. Next, a decision tree approach and a structural equation model are combined to examine cause-effect relationships between health-related QOL indicators and their influencing factors. It is found that realizing compact cities with city hall, education facilities, hospitals and/or parks, and public transportation systems in the centers (urban structures are different between megacities and other cities) is effective to the health promotion.

Keywords: urban form, health-related QOL, physical health, mental health, social health, travel behavior, park, decision tree, structural equation model, Japan

INTRODUCTION

Enhancing people's quality of life (QOL) is one of common goals of public policies. To evaluate the QOL, health is an indispensible element (Knox, 1975; Diener, 1984; Phillips, 2006). In the famous OECD Better Life Index[1], health is included. Looking at the ranking by the 34 member countries, the average life expectancy in Japan boasts the top; however, its self-reported health conditions are lower, ranked as the 12th place. In 1986, Ottawa Charter for Health Promotion was adopted by World Health Organization (WHO), where not only individual efforts but also social environment improvement are emphasized in the health promotion. Initiated by WHO in 1986, healthy cities have spread rapidly across Europe and

[1] OECD Better Life Index: http://oecdbetterlifeindex.org/

other parts of the world. In Japan, "Healthy Japan 21"[2], a national program for the health promotion, has been started since 2000. In 2002, the Health Promotion Act was enacted. In 1964, WHO defined that "health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". In other words, healthy life means a balanced condition of not only physical health, but also mental and social health. And QOL directly linked with health is usually called health-related QOL (Keller et al., 1998; Ware, 2004; Suzukamo et al., 2011). Even though health cities have been proposed for many years, little has been done with respect to the study of the health-related QOL in a comprehensive way. Thus, it is not difficult to imagine that health policies in practice have been implemented in an impromptu manner.

Motivated by the above issues in promoting healthy cities, this study will first implement a comprehensive survey that contains the health-related QOL and its potential influencing factors by reflecting the insights from different scientific fields, and then propose a two-stage modeling method to systematically explore the cause-effect relationships existing in the health-related OQL and its influencing factors. For this purpose, this study adopts an interdisciplinary approach, which integrates the knowledge of health science, transportation and urban planning. The survey was conducted via the Internet with respect to residents residing in major Japanese cities (20 cities) in 2010, and 1,172 samples were successfully collected. In the analysis, megacities (3 cities) and local cities (17 cities) are distinguished consider that different types of urban forms and health promotion environments might have different impacts on the health-related QOL.

HEALTH-RELATED QOL

Several typical methods have been proposed to measure the health-related QOL. Among these methods, SF-36 (Short-Form 36)[3] is one of the most widely used generic measures of health-related QOL and has been adopted by more than 110 countries. The Short Form-36 was derived from the General Health Survey of the Medical Outcomes Study by Stewart and colleagues (see Ware and Sherbourne, 1992, and McHorney et al., 1993). Population-based normative data on the SF-36 is available for the United States, Japan, and some other countries as well. SF-36 does not limit the types of population and is a comprehensive health-related QOL measure, where eight subscales (physical functioning (PF), limitations on role functioning because of physical health (RP), bodily pain (BP), general health (GH), mental health (MH), limitations on role functioning because of emotional problems (RE), social functioning (SF), and vitality (VT)) and totally 36 items are included. Details are shown in Table 1.

Reflecting recent research findings, this study adopts the three-component model of SF-36 (Suzukamo et al., 2011), as shown in Figure 1, rather than the conventional two-component model (Keller et al., 1998; Ware, 2004).

[2] http://www.kenkounippon21.gr.jp/
[3] http://www.sf-36.org/

Table 1 – Health-related QOL indicators

Indicators	**Question contents**
physical functioning (PF) The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?	Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports
	Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf
	Lifting or carrying groceries
	Climbing several flights of stairs
	Climbing one flight of stairs
	Bending, kneeling, or stooping
	Walking more than a mile (a kilometer in Japanese version)
	Walking several blocks (about several hundred meters in Japanese version)
	Walking one block (about one hundred meters in Japanese version)
	Bathing or dressing yourself
limitations on role functioning because of physical health (RP) During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?	Cut down the amount of time you spent on work or other activities
	Accomplished less than you would like
	Were limited in the kind of work or other activities
	Had difficulty performing the work or other activities (for example, it took extra effort)
bodily pain (BP)	How much bodily pain have you had during the past 4 weeks?
	During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?
general health (GH)	In general, would you say your health is? (Excellent, very god, good, fair, poor)
	I seem to get sick a little easier than other people.
	I am as healthy as anybody I know.
	I expect my health to get worse.
	My health is excellent.
vitality (VT)	Did you feel full of pep?
	Did you have a lot of energy?
	Did you feel worn out?
	Did you feel tired?
social functioning (SF)	During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?
	During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?
limitations on role functioning because of emotional problems (RE) During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?	Cut down the amount of time you spent on work or other activities
	Accomplished less than you would like
	Didn't do work or other activities as carefully as usual
mental health (MH)	Have you been a very nervous person?
	Have you felt so down in the dumps that nothing could cheer you up?
	Have you felt calm and peaceful?
	Have you felt downhearted and blue?
	Have you been a happy person?
Health transition (HT)	Compared to one year ago, how would you rate your health in general now?

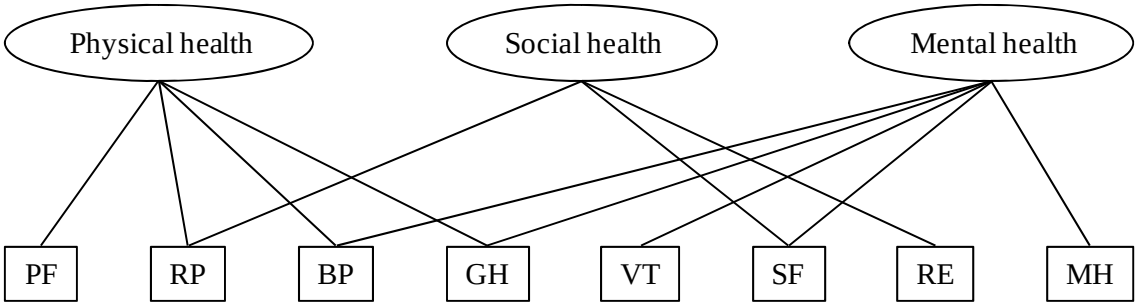

Figure 1 – Health-related QOL with three-factor structure

EXISTING STUDIES

There are various factors that might influence the health-related QOL. Careful review suggests that lifestyle habit, health promotion activities, travel behavior, park usage, residential environment, and urban infrastructure are relevant to the health-related QOL.

Internationally, lifestyle habit has been measured based on the famous Breslow's (1965) seven habit categories (i.e., smoking, drinking alcohol, physical exercise, weight management, sleep, breakfast consumption and snacking) (Belloc and Breslow, 1972). To reflect the cultural difference, Morimoto (1987) proposed eight indices that are more suitable to measure Japanese lifestyle habit: regular exercise, alcohol consumption, smoking, sleeping pattern, nutritional balance, breakfast, working pattern, and subjective stress. Other methods are briefly reviewed by Wada et al. (2009), but the most popular measure in Japan is Morimoto's eight indices. It is revealed that these lifestyle habits are closely related to the pathogenesis lifestyle-related diseases (e.g., cancer, cardiac disease, and cerebrovascular disease) in Japan (Tokunaga and Yamasaki, 2008).

Exercise and physical activities are two of major health promotion activities. Exercise is beneficial to improve the metabolic syndrome (e.g., obesity, hypertension, hyperglycemia, and lipid abnormality) (e.g., Sato et al., 2007; Gayda et al., 2008). Effects of physical activities on the health promotion have also widely examined (e.g., Janney et al., 2008; Iannotti et al., 2009; Lindwall et al., 2012).

Transport and health are interlinked at many levels, with transport directly and indirectly influencing health, and health status influencing transport options (e.g., Le Tertre et al., 2002; Hodgson et al., 2012). Dhondt et al. (2013) evaluated the health impact of a policy resulting in an increase of car fuel prices by 20% on active travel, outdoor air pollution and risk of road traffic injury, and found that a 20% fuel price increase leads to an overall gain of 1650 (1010–2330) DALY (Disability Adjusted Life Years). In the Australian context, Mulley et al. (2013) estimated that each additional hour spent in a car per day was associated with a 6% increase in the likelihood of obesity while each additional hour spent walking per day was associated with a 4% decrease in the chance of obesity, and also suggested to include the health benefits of sustainable transport in transportation appraisal frameworks. In Japan, Muromachi (2008)

confirmed that BMI (Body Mass Index) is higher in residential areas with higher share of car-dependent commuting trips and BMI is lower in areas with more walk trips.

Related to environmental factors, Saito et al. (2011) found that high residential density, good access to shops, presence of sidewalks and no household motor vehicles were associated with longer walking time for transportation, not owing household motor vehicles for male and presence of bike lanes, social environment, and aesthetics for female were positively associated with the prevalence of metabolic syndrome. Kano et al. (2004) reported that park usage leads to the decline of anxiety and tension, depression, anger, tiredness, and confusion.

There are more relevant studies; however, little has been done to look at all these factors affecting the health-related QOL jointly in a consistent way. Reviews of existing studies motivated us to design a comprehensive questionnaire that contains major factors included and measure all the three aspects of health-related QOL and evaluate the influence of these factors in a unified modeling framework. It is expected that such challenges could provide seamless views that are crucial to decisions on health policies.

SURVEY

Survey Design

The questionnaire consists of health conditions, lifestyle habit, health promotion activities, park usage, daily activity and travel, residential environment, QOL (happiness and life satisfaction), and individual and household attributes (see Table 2). These contents are selected based on careful literature review.

To capture health conditions, experience of serious diseases, interpersonal communication (social capitals), and health-related QOL are included in the questionnaire. The health-related QOL is measured by using the international standard survey form "SF-36"[4], which contains eight subscales: physical functioning (PF), limitations on role functioning because of physical health (RP), bodily pain (BP), general health (GH), mental health (MH), limitations on role functioning because of emotional problems (RE), social functioning (SF), and vitality (VT).

Lifestyle habit is measured with eight items based on 5-point scaling method (higher score means better habit): 1) take breakfast every day (take breakfast: TB), 2) sleep for seven to eight hours per day on average (enough sleep: NS), 3) have a meal with balanced tuition (balanced meal: BM), 4) do not smoke (non-smoke: NS), 5) perform physical exercise and sports regularly (health activities: HA), 6) do not drink alcohol too much (no-drink: ND), 7) work less than nine hours per day on average (healthy work: HW), and 8) there is little subjective stress (little stress: LS).

[4] This study adopted the newest version of SF-36 (SF-36v2™) with the formal permission from the iHope International in Japan (http://www.i-hope.jp/)

Table 2 – Questionnaire Contents

Category	Description
Health conditions	1) Body weight and height, history of serious disease 2) Interpersonal communication: human trust, evaluation of altruism, community organization belonging, number of community organizations 3) Subjective evaluation of current health condition, change of health condition, 4) Eight subscales (34 items) of health-related QOL (physical functioning (PF), limitations on role functioning because of physical health (RP), bodily pain (BP), general health (GH), mental health (MH), limitations on role functioning because of emotional problems (RE), social functioning (SF), and vitality (VT))
Lifestyle habit	Eight types of habits: take breakfast, enough sleep, balanced meal, non-smoking, health activity, no-drinking, healthy work, little stress
Health promotion activities	1) Types: strenuous exercise with bodily collision (soccer, basketball, etc.), strenuous exercise without bodily collision (tennis, training with equipment, badminton, etc.), calm exercise without bodily collision (golf, bowling, walking, etc.), social activities (voluntary activities, community activities, events, socializing with people, etc.), communication activities with family members 2) Attributes by health activity type: frequency, time period, activity duration, activity site (in-home, park, in-door sport facility, work place or school, mountain, river, sea, etc.), companion, and main travel mode to activity site 3) Affective experience during physical exercise, social activities, family communication activities 4) Change of health promotion activity frequency in recent years
Park usage	1) Type of activity performed at park: walking, walking with dogs, relaxed rest, play with kids, physical exercise, enjoy watching flowers, trees or nature, enjoy talking, and no visit 2) Attributes by activity type: frequency, time period, activity duration, size of park, facilities inside park, companion, main travel mode to park, travel distance and time from home to park 3) Affective experience and satisfaction of park usage (nine items: size, function (health appliances and other appliances), nature, location, access to park, user manner, park management, overall satisfaction) 4) Influence of park usage on health, change of park visit in recent years, preferred appliances inside park, willingness to pay for health promotion appliances introduced to park
Daily activity and travel	1) Type of activity: commuting/schooling, business, shopping, non-academic learning and research, hobby/recreation/leisure/socializing, social activity, health care, eating out, personal affairs (go to bank, governmental office, etc.) 2) Attributes by activity type: frequency, main travel mode, distance from home to activity site 3) Affective experience
Residential environment	Type of residence (apartment, detached house, collective house, etc.; building floors, the floor of residing, installation of elevator), distance to nearest urban facilities (city hall, post office/bank, kindergarten and nursery school, elementary school, secondary school, high school, hospital, community center, station, bus stop, supermarket, park
Current QOL	1) Happiness 2) life satisfaction by life domain: residential environment, family budget, health condition, relationship with neighborhood, education, job, family life, leisure and recreation 3) Overall life satisfaction
Individual attributes (seven items)	Gender, age, residence location (zip code), occupation, relationship with household head, driving license ownership, and ownership of dedicated car
Household attributes	number of household members (pre-school children, elementary school children, secondary school children, high school children, university students, employed members, and the elderly members), household income

Health promotion activities include physical exercise, social activities, and family communication. For each type of activity, frequency, time period (weekday or weekend, time of a day), activity duration, activity site, companion, and access mode to activity site as well as affective experience during activity participation are reported. In addition, change of activity in recent years is also investigated.

Park is one of the most familiar places for people. Here park usage is investigated by asking respondents to report the type of activity, frequency, activity time period, activity duration, size of park, facilities inside park, companion, main travel mode to park, travel distance and time from home to park, affective experience and satisfaction during park usage, subjective evaluation of influence of park usage on health, change of park visit in recent years, preferred appliances inside park, willingness to pay for health promotion appliances introduced to park.

Both activity and travel behavior are also targeted. Travel mode, trip frequency, travel distance by mode and activity are reported together with affective experience during travel.

It is expected that residential environment might be also influential to the health promotion. To clarify this expectation, we include residential location, residence duration, type of residence, distance to nearest urban facilities to measure residential environment.

Survey Implementation

The survey was implemented in November 2010 with respect to residents residing in major Japanese cities: three megacity metropolitan areas and other government-ordinance-designated cities (in total, 20 cities). The survey was done with the help of a major Internet survey company, which had more than 1.4 million registered members. Respondents were randomly selected by reflecting the representative attributes (age, gender, and residential locations) of the population. Target number of samples was set to 1,000 persons. To reach this target, 14,534 registered members were contacted between November 22 and 29. As a result, 1,172 samples were successfully collected (586 in megacities and 586 in local cities). The return rate was about 8%.

Concerning the representativeness of population, Figure 2 shows the evaluation scores of health-related QOL for the eight subscales: PF, RP BP, GH, VT, SF, RE, and MH. One can see from Figure 2 that residents in megacities and local cities show similar scores of subscales to the population. In this sense, it can be said that the collected samples show representative health-related QOL.

CAUSE-EFFECT ANALYSIS OF HEALTH-RELATED QOL

There are various factors affecting health-related QOL and these factors themselves might be also correlated with each other. Looking at Table 2, possible influencing factors include lifestyle habit, health promotion activities, daily activity and travel, residential environment, and individual and household attributes. To clarify cause-effect relationships between the

above variables, literature review could be helpful. However, careful reviews suggest that there are no any consistent observations. Therefore, we decide to empirically explore the above cause-effect relationships directly from the data collected. For each type of variable category, there are also different attributes, and especially some variable categories even include several ten items. To effectively capture the above cause-effect relationships by avoiding analysts' arbitrary judgments, we develop a two-stage modeling approach. In the first step, we apply a data mining approach, called exhaustive CHAID (Chi-squared Automatic Interaction Detector), to identify how variables in different categories are associated with each other, where these variables include our target dependent variables (i.e., the eight subscales of health-related QOL) and their potential influencing factors. In the second step, a structural equation model (SEM) is applied to concretely estimate the identified cause-effect structures.

Figure 2 – Evaluation scores of health-related QOL

CHAID (Kass, 1980) is one of the most popular methods used in science and business for performing classification or segmentation. It uses the given data to automatically build a series of "if-then" rules (in the form of decision tree) that can classify the sample with maximum accuracy, than when using traditional exploratory statistical methods. Decision trees are charts that illustrate decision rules. They begin with one root (parent) node that contains all of the observations in the sample. The process is then applied recursively to subgroups to define sub-subgroups, and so on, until the tree is converged based on certain stopping criteria. However, sometimes CHAID may not find the optimal split for a variable, since it stops merging categories as soon as it finds that all remaining categories are statistically different. Accordingly, Exhaustive CHAID (Biggs et al, 1991) was developed to remedy this issue by continuing to merge categories of the predictor variable until only two super categories are left. It then examines the series of merges for the predictor variable and finds the set of categories that gives the strongest association with target variable. Thus, Exhaustive CHAID can find the best split for each predictor variable.

Concretely speaking, when applying exhaustive CHAID in this study, each variable is first picked up and then use the remaining variables to explain it (note: the eight subscales of health-related QOL are not used to explain other variables). Especially, since it is expected that different types of cities might have different types of cause-effect structures, here, the selected 20 major Japanese cities are re-grouped into two categories: megacities (i.e., three megacity metropolitan areas (Tokyo, Nagoya and Osaka) and local cities (other government-ordinance-designated cities (17 cities)). Exhaustive CHAID is applied to these two types of cities, separately. Based on the above identified cause-effect structures, SEM models are further estimated. Exhaustive CHAID analysis results are shown in Table 3, and Figures 3 and 4. SEM results are shown in Figures 5 and 6, and Tables 4 and 5. These results are described below.

Analysis Results based on Exhaustive CHAID

Table 3 shows the results of exhaustive CHAID analysis and Figures 3 and 4 illustrate the identified cause-effect structures for the two types of Japanese cities.

Lifestyle habit

For both megacities and local cities, especially, stress significantly influences the subscales of health-related QOL, except PF. Therefore, it can be assumed that lifestyle habit affects physical, mental, and social health for both types of cities. Breakfast is statistically influential to social activities in local cities, and breakfast to social activities in megacities. Habit of physical exercise affects the time use of physical exercise in both types of cities, social activities and family communication in local cities. In this sense, it seems logical to assume that lifestyle habit also influences health promotion activities.

Health promotion activities

Except family communication, other two aspects of health promotion activities statistically affects PF, RP, GH, VT, SF, and RE in megacities, PF, RP, GH, and VT in local cities. With this result, we assume that health promotion activities affect three aspects of health-related QOL, i.e., physical, mental, and social health.

Travel behavior

It is observed that PF in megacities, RP and BP in local cities are influenced by travel behavior. Following the three-factor structure of health-related QOL, we can reasonably assume that travel behavior is influential to physical health in megacities, and all the three aspects of health-related QOL in local cities.

Table 3 – Estimation results of Exhaustive CHAID

Child node		Parent node	Health-related QOL																Lifestyle habit														Health promotion activities						Travel behavior					
			PF		RP		BP		GH		VT		SF		RE		MH		TB		ES		BM		NS		HA		ND		HW		LS		EF		SA		FM		WB		CR		PT	
			MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC
Lifestyle habit (1 ~ 5 points) Higher point means good habit	Take breakfast	TB																																												*
	Enough sleep	ES	*																																										*
	Balanced meal	BM																*																			*									
	Non-smoke	NS						*																																					
	Health activity	HA	*							*																									*	*		*		*					*	
	No-drink	ND																																												
	Healthy work	HW							*		*																																		
	Less stress	LS			*	*	*	*	*	*	*	*	*	*	*	*	*	*																											
Health promotion activities (time use: hours/week)	Physcial exercise	EF	*	*		*			*	*	*	*	*														*	*											*	*					*	
	Social activities	SA			*										*				*	*			*		*	*															*				*	
	Family communication	FM																																												
Travel behavior Main travel mode (Yes 1, No: 0)	Walk / bicycle	WB	*			*		*																						*		*			*									
	Motorcycle / car	CR																		*										*														
	Public transport	PT	*																																										
Living environment Distance to nearest facilities (km)	City hall																								*																					
	post office / bank																																													
	Kindergarden / nursery school																				*																									
	Elemntary school																						*																						
	Secondary school																																													
	High school																																													
	Hospital																										*																		
	Community center																												*																
	Station																																												*	
	But stop					*																																								
	Supermarket																																													
	Park				*																								*																
Urban infrastructure	Water supply improvement rate (%)					*									*												*			*															
	Number of beds in hospitals (bed)																																													
	Park area (km^2)																																													

Note: "*" means that child node is statistically influential to parent node at 5% level; MC indicates megacities and LC refers to local cities.

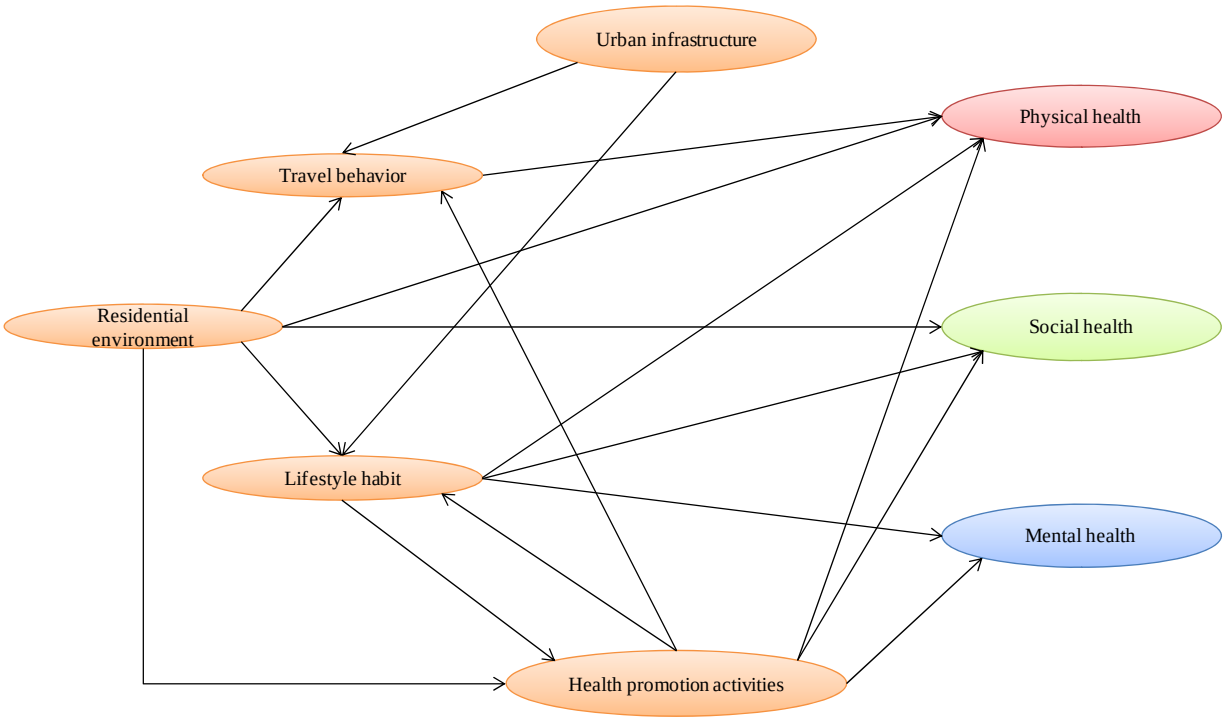

Figure 3 – Assumed cause-effect structure in megacities of Japan based on exhaustive CHAID

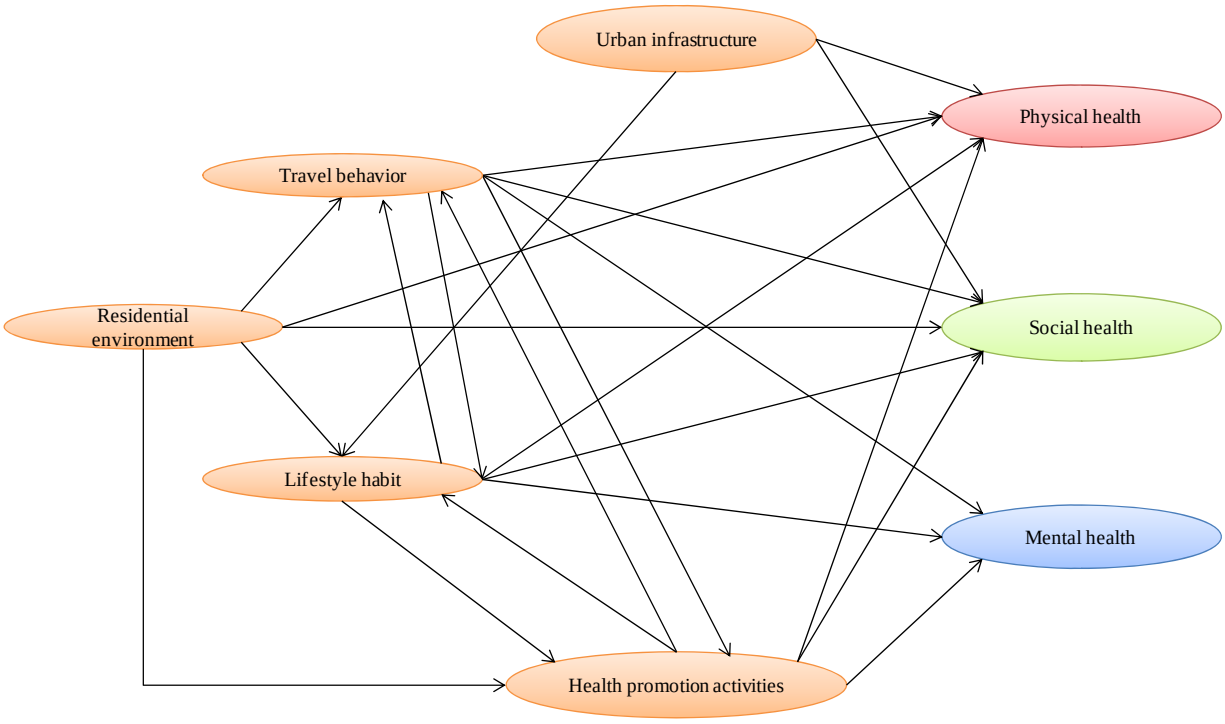

Figure 4 – Assumed cause-effect structure in local Japanese cities based on exhaustive CHAID

Residential environment

Distance to nearest park in megacities and distance to nearest bus stop in local cities affect the subscale RP of health-related QOL. It is therefore assumed that residential environment is influential to physical and social health in both types of cities. As for the influence of residential environment on lifestyle habit, distance to nearest post office and/or bank affects the habit of smoking, distance to kindergarten and/or nursery school affects the sleeping habit, distance to hospital affects the habit of alcohol drinking. Accordingly, we assume that residential environment is influential to lifestyle habit. Among the three aspects of health promotion activities, the time use of family communication is affected by distance to hospital in megacities and distance to nearest park in local cities. Even though the other two aspects of health promotion activities are not influenced by the variables of residential environment, it is still reasonable to assume that residential environment influences health promotion activities.

Urban infrastructure

Due to the data availability, here, only water supply improvement rate, number of beds in hospitals, and park area are adopted to measure the level of urban infrastructure improvement. It is found that there are not any indicators of urban infrastructure affecting health-related QOL in megacities. In local cities, water supply improvement rate is related to the subscales RP and RE of health-related QOL. As shown in Figure 1, RP and RE is associated with physical and social health. Therefore, we assume that urban infrastructure affects physical and social health in local cities, but not any aspects of health-related QOL in megacities. Lifestyle habit is only influenced by water supply improvement rate. Concretely, the habit of physical exercise and work in megacities, the alcohol drinking habit in local cities are statistically related to urban infrastructure. Therefore, we assume that urban infrastructure is influential to the lifestyle habit in both types of cities. On the other hand, only in megacities, walk and bicycle usage is associated with urban infrastructure. In this study, we assume that urban infrastructure influences travel behavior only in megacities.

Analysis Results based on Structural Equation Models

We first estimated the cause-effect models shown in Figures 3 and 4, but we failed to estimate the models when we introduced the relationships between travel behavior and health promotion activities, between travel behavior and lifestyle habit. With this reason, we re-estimated the models by excluding these relationships. The results are shown in Figures 5 and 6, respectively. The model accuracy indicators, GFI and AGFI, are higher than 0.8 and RMSEA is about 0.06. It is therefore convincible to say that the model accuracy is good enough.

Standardized estimation results (including direct effects and total effects) are shown in Tables 4 and 5.

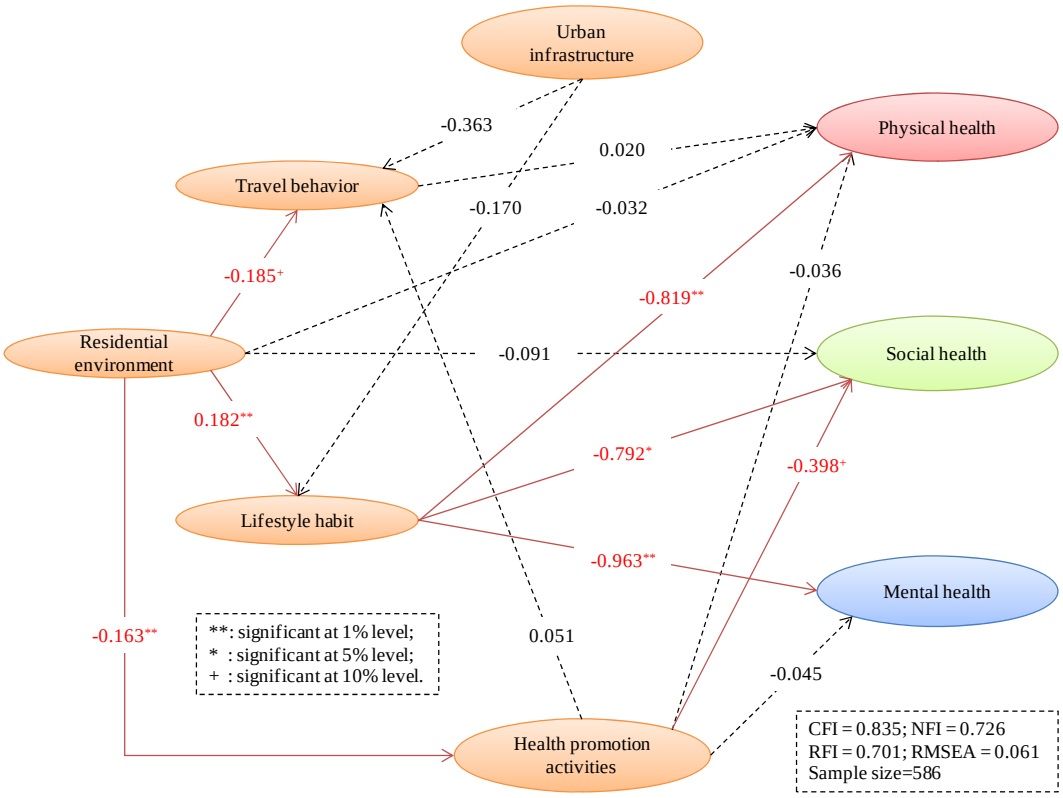

Figure 5 – Estimated cause-effect structure in megacities of Japan based on exhaustive CHAID

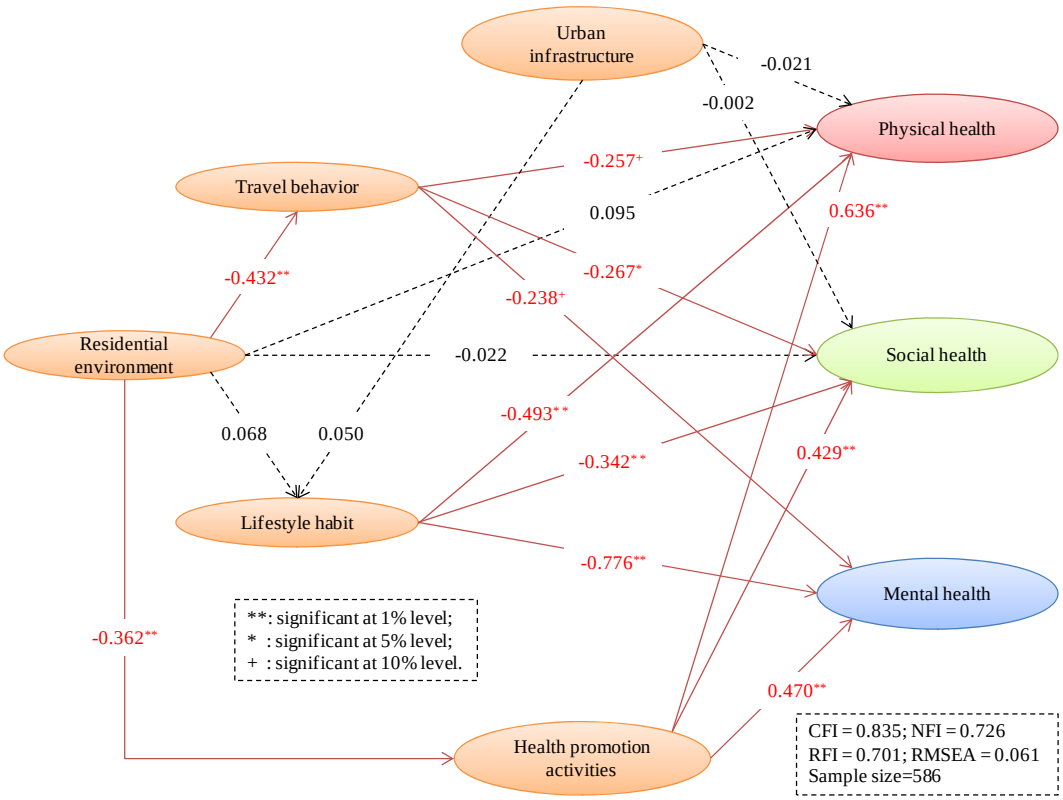

Figure 6 – Estimated cause-effect structure in local Japanese cities based on exhaustive CHAID

Table 4 – Standardized total effects: Megacities of Japan

Endogenous variables \ Exogenous variables		Residential environment	Urban infrastructure	Health promotion activities	Lifestyle habit	Travel behavior	Mental health	Social health	Physical health
Health-related QOL	Mental health	-0.151 **	0.142 +	0.014	-0.809 **				
	Social health	-0.109	0.083 *	-0.197 **	-0.474 **				
	Physical health	-0.152	-0.010	0.186	-0.269 **	0.159 +			
Factors affecting health-related QOL	Health promotion activities	-0.157 **							
	Lifestyle habit	0.184 **	-0.176						
	Travel behavior	-0.191 *	-0.362 +	0.030					
Health-related QOL (Eight subscales: higher point means good QOL)	Mental health (MH)	-0.125 **	0.118 +	0.011	-0.672 *		0.830 (-)		
	Limitations on role functioning because of emotional problems (RE)	-0.107	0.082 *	-0.193	-0.464 **			0.978 **	
	Social functioning (SF)	-0.100 *	0.088 +	-0.059	-0.498 *		0.424 **	0.328 +	
	Vitality (VT)	-0.131 **	0.123 +	0.012	-0.703 **		0.868 **		
	General health (GH)	-0.136 **	0.085 +	0.060	-0.576 **	0.044	0.620 **		0.276 **
	Bodily pain (BP)	-0.108 **	0.059 +	0.058	-0.426 *	0.045	0.433 **		0.282 **
	Limitations on role functioning because of physical health (RP)	-0.124	0.046	-0.047	-0.388 **	0.061		0.602 (-)	0.383 **
	Physical functioning (PF)	-0.106	-0.007	0.130	-0.188 +	0.111			0.699 (-)
Lifestyle habit (1 ~ 5 points: higher point means good habit)	Take breakfast (TB)	0.045 **	-0.043 *		0.243 **				
	Enough sleep (ES)	0.070 **	-0.067 *		0.378 **				
	Balanced meal (BM)	0.077 **	-0.074 *		0.419 **				
	Non-smoke (NS)	0.039 **	-0.038 *		0.214 **				
	Health activity (HA)	0.053 **	-0.050 *		0.286 **				
	No-drink (ND)	0.033 **	-0.032 *		0.181 **				
	Healthy work (HW)	0.064 **	-0.062 *		0.350 **				
	Less stress (LS)	0.140 **	-0.134 *		0.762 (-)				
Health promotion activities (hours/week)	Physcial exercise	-0.101 *		0.644 *					
	Social activities	-0.084 **		0.532 *					
	Family communication	-0.079 **		0.503 (-)					
Residential environment (Distance to nearest facilities from home: km)	City hall	0.253 **							
	post office / bank	0.831 **							
	Kindergarten / nursery school	0.750 **							
	Elementary school	0.661 **							
	Secondary school	0.670 **							
	High school	0.427 **							
	Hospital	0.502 **							
	Community center	0.655 **							
	Station	0.519 **							
	But stop	0.679 **							
	Supermarket	0.695 **							
	Park	0.780 (-)							
Urban infrastructure	Water supply improvement rate (%)		-0.108 +						
	Number of beds in hospitals (bed)		0.258 *						
	Park area (km^2)		0.885 (-)						
Travel behavior (Main travel mode: Yes-1, No-0)	Public transport	-0.076 *	-0.144 *	0.012		0.397 **			
	Motorcycle / car	0.094 *	0.179 +	-0.015		-0.494 **			
	Walk / bicycle	-0.056 *	-0.106 *	0.009		0.293 (-)			

(Note) **: significant at 1% level; *: significant at 5% level; +: significant at 10% level; (-): fixed to be unity during model estimation.

Table 5 – Standardized total effects: Local Japanese Cities

Endogenous variables \ Exogenous variables		Residential environment	Urban infrastructure	Health promotion activities	Lifestyle habit	Travel behavior	Mental health	Social health	Physical health
Health-related QOL	Mental health	-0.113 +	-0.042	0.396 **	-0.777 **	-0.207 *			
	Social health	-0.084	-0.016	0.471 *	-0.337 **	-0.275 *			
	Physical health	-0.089	-0.002	0.575 *	-0.067	-0.232			
Factors affecting health-related QOL	Health promotion activities	-0.375 **							
	Lifestyle habit	0.067	0.053						
	Travel behavior	-0.425 **							
Health-related QOL (Eight subscales: higher point means good QOL)	Mental health (MH)	-0.095 +	-0.035	0.335 **	-0.659 +	-0.175 *	0.847 (-)		
	Limitations on role functioning because of emotional problems (RE)	-0.082	-0.015	0.464 +	-0.332 +	-0.270 *		0.984 **	
	Social functioning (SF)	-0.074 +	-0.021	0.336 *	-0.407 *	-0.188 *	0.338 **	0.429 **	
	Vitality (VT)	-0.099 +	-0.037	0.348 **	-0.684 +	-0.182 *	0.880 **		
	General health (GH)	-0.093 *	-0.023	0.423 **	-0.433	-0.196 +	0.525 **		0.375 **
	Bodily pain (BP)	-0.070 +	-0.012	0.357 **	-0.243 +	-0.157 +	0.275 **		0.433 **
	Limitations on role functioning because of physical health (RP)	-0.086 +	-0.010	0.508 *	-0.233	-0.257 *		0.616 (-)	0.378 **
	Physical functioning (PF)	-0.060	-0.001	0.383 *	-0.045	-0.155			0.667 (-)
Lifestyle habit (1 ~ 5 points: higher point means good habit)	Take breakfast (TB)	0.018	0.015		0.274 **				
	Enough sleep (ES)	0.017	0.013		0.252 **				
	Balanced meal (BM)	0.025	0.020		0.370 **				
	Non-smoke (NS)	0.009	0.007		0.136 **				
	Health activity (HA)	0.020	0.016		0.300 **				
	No-drink (ND)	0.003	0.002		0.044				
	Healthy work (HW)	0.019	0.015		0.280 **				
	Less stress (LS)	0.055	0.044		0.819 (-)				
Health promotion activities (hours/week)	Physcial exercise	-0.139 *		0.369 **					
	Social activities	-0.092 *		0.245 **					
	Family communication	-0.129 *		0.344 (-)					
Residential environment (Distance to nearest facilities from home: km)	City hall	0.378 **							
	post office / bank	0.546 **							
	Kindergarten / nursery school	0.607 **							
	Elementary school	0.612 **							
	Secondary school	0.700 **							
	High school	0.492 **							
	Hospital	0.684 **							
	Community center	0.567 **							
	Station	0.596 **							
	But stop	0.498 **							
	Supermarket	0.629 **							
	Park	0.404 (-)							
Urban infrastructure	Water supply improvement rate (%)		0.524 **						
	Number of beds in hospitals (bed)		0.983 **						
	Park area (km^2)		0.560 (-)						
Travel behavior (Main travel mode: Yes-1, No-0)	Public transport	-0.066 *				0.154 *			
	Motorcycle / car	0.184 **				-0.432 **			
	Walk / bicycle	-0.250 **				0.587 (-)			

(Note) **: significant at 1% level; *: significant at 5% level; +: significant at 10% level; (-): fixed to be unity during model estimation.

Direct effects

The common observations in both types of cities are, 1) lifestyle habit and health promotion activities affect social health and lifestyle habit influences mental health, but residential environment is not influential to health-related QOL, 2) residential environment influences health promotion activities and travel behavior, but urban infrastructure does not affect lifestyle habit. Concerning the differences between the two types of cities, travel behavior affects physical health, residential environment affects lifestyle habit, urban infrastructure affects travel behavior, and lifestyle habit affects physical health in megacities; however, these influences are not statistically significant. On the other hand, in local cities, health promotion activities are influential to mental health, travel behavior to social and mental health, but these influences are not confirmed in megacities.

Total effects on health-related QOL

In megacities, the most influential factor on health-related QOL is lifestyle habit (standardized values of parameters: -0.269 for physical health, -0.809 for mental health, and -0.474 for social health). On the other hand, in local cities, the most influenced health-related QOL by lifestyle habit is mental health (-0.777), health promotion activities most affect physical health (0.575) and social health (0.471). Travel behavior is significantly influential to physical health in megacities, mental and social health in local cities. Health promotion activities significantly affect all the three aspects of health-related QOL in local cities, but only social health in megacities. The influence of urban infrastructure on health-related QOL (except physical health) is confirmed in megacities, but the influence is not confirmed with respect to any of the three aspects of health-related QOL. For residential environment, its influence only on mental health is observed.

Travel behavior and health-related QOL

Significant influence of travel behavior on health-related QOL is confirmed in both types of cities. In megacities, the physical health level of public transport, walk and bicycle users is high, and that of motorcycle and car users is low. On the other hand, all the three aspects of health-related QOL show higher values for motorcycle and car users and lower values for other travel mode users. These results are consistent with the cross-aggregation analysis results. This might be in part due to the use of dummy variables to describe travel behavior. To explain the meanings of estimation results, the magnitude of the influence of each travel behavior variable on the QOL is inversely proportional to the estimated parameter of each travel behavior variable. This is a general rule to explain the influence of observed variables described by exogenous latent variables on endogenous variables (both latent and observed variables). Keeping this rule in mind, it is obvious that the influence of walk and bicycle on the QOL (0.293) is highest in megacities, and public transport (0.154) shows the highest

influence on the QOL in local cities. The second largest influencing factor is public transport in megacities and motorcycle and car in local cities.

Residential environment and health-related QOL

This part of analysis is especially linked with discussion of urban forms in this study. In both types of cities, the shorter the distance to neighboring urban facilities, the better the level of health-related QOL. In other words, putting major urban life facilities close to each other is beneficial to the improvement of health conditions. This finding directly supports the argument that compact city development is not only good for improving environmental quality but also good for improving human health. Among the neighboring facilities, shortening the distance to city hall is most influential to the improvement of health (0.253 in megacities and 0.378 in local cities). The second largest influencing distance variables are high school, hospitals and stations in megacities (0.427, 0.502 and 0.519), and park, high school and bus stop in local cities (0.404, 0.492 and 0.498). As for the often used supermarket in daily life, its influence on health-related QOL is moderate. In any city, residential environment does not directly influence the health-related QOL, but impose its influence via health promotion activities and lifestyle habit. All the distance variables are positively influential to lifestyle habit and negatively to health promotion activities. This means that residents living close to their neighboring urban facilities show bad lifestyle habits, but active health promotion activities. In other words, compact city development might discourage people's better lifestyle habits, but encourage people's health promotion activities. This intuitively looks contradictory, but looking at the distributions of distances and habit scores, on average, distances to most of neighboring urban facilities are slightly longer in local cities than in megacities, and habit scores are slightly lower in local cities and higher in megacities. In summary, strengthening governmental and educational functions in central urban areas as well as supportive public transportation systems as a strategy to promote compact city development contributes to the promotion of people's health as well as their QOL. Furthermore, while promoting residence in central urban areas, introducing more hospitals (leading to shorter distance to hospitals on average) in central areas of megacities and more parks (leading to shorter distance to parks on average) in central areas of local cities are more beneficial to the improvement of health-related QOL than other types of urban facilities.

Urban infrastructure and health-related QOL

All the three indicators (water supply improvement rate, beds in hospitals, and park area) of urban infrastructure are statistically significant. The influence of urban infrastructure on health-related QOL and lifestyle habit is confirmed in megacities, but not in local cities.

Health promotion activities and health-related QOL

In local cities, increasing health promotion activities tends to improve the eight subscales of health-related QOL in local cities, but is likely to worsen RE, SF and RP in megacities.

Lifestyle habit and health-related QOL

In both types of cities, improving lifestyle habits contributes to the improvement of all the eight subscales of health-related QOL. This is especially true for the alcohol drinking habit in megacities, the smoking, sleeping, and breakfast habits in local cities.

CONCLUSIONS

Aiming to provide new insights into decisions on health promotion policies, this study first designed a comprehensive questionnaire that capture the health-related QOL in a comprehensive way, and its influencing factors, including health promotion activities at an individual level, travel behavior, and residential environment and so on. And then, a web-based survey was implemented with respect to major Japanese cities in 2010 and 1,172 questionnaire sheets were successfully collected. To effectively clarify the influencing factors on the health-related QOL, we further proposed a two-stage modeling method. At the first stage, a data mining approach called Exhaustive CHAID is applied to identify potential cause-effect relationships between health-related QOL and its influencing factors, and between influencing factors themselves. At the second stage, a structural equation model is applied to concretely confirm the identified cause-effect relationships. The effectiveness of the approach is empirically confirmed.

Model estimation results suggest that improving the health-related QOL requires the consideration of different types of cities. It is re-confirmed that lifestyle habit and health promotion activities will be still important to improve the health-related QOL. Compact city development should be further encouraged by strengthening residential function, governmental function, educational function, and park functions as well as supportive public transportation systems with careful consideration of city differences. In Japan, “Healthy Japan 21”[5] is a national program to promote the health based on the Health Promotion Act. However, this national program mainly focuses on the improvement of lifestyle habit and health promotion activities. Differently, this study confirmed that not only lifestyle habit and health promotion activities, but also other factors (here, daily activity and travel behavior, and residential environment) should be simultaneously reflected in the program. This study provides not only a comprehensive survey method, but also an effective analysis method for supporting policy decisions on the health-related QOL.

Future studies should be done by making full use of all the survey contents of this study. It might be better to re-examine findings from existing studies using the current comprehensive dataset by properly considering cultural differences. The observed findings should be given scientific explanations in a more robust way rather than subjective inferences. For this purpose, it might be worth implementing in-door and outdoor experiments from different scientific perspectives based on a more innovative interdisciplinary approach. Finally, it is important to clarify how to utilize the interdisciplinary findings to support decisions on cross-sectoral health policies.

[5] http://www.kenkounippon21.gr.jp/

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