The Impact of Built Environment on Residents' Health from the Perspective of Physical Activity

Dissertation

The Impact of Built Environment on Residents' Health from the Perspective of Physical Activity

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Abstract

Rapid urbanization has made great contribution to the development of the world economy, and also brought various "urban diseases" to human beings, which seriously threaten the health of urban residents. In order to better solve urban problems and improve people's health, the World Health Organization put forward the concept of “Healthy City”, which had become a global strategic action. China also determined the national strategy of "Healthy China" in 2016, and proposed to integrate health into the whole process of urban and rural planning, construction and governance. The relationship between built environment and public health has always been the focus of urban planning. Specific environmental characteristics, spatial characteristics and health activity have become new important areas of urban planning research. This PhD research focused on the interaction between the daily health behavior of residents and the built environment at the community scale. What are the influence factors of built environment on public health and how does it affect health of residents.

This dissertation took Fuzhou City of Fujian Province in China as the research object. The data of business, life service, catering, sports, green space, public transportation in Fuzhou were obtained through a map website. The data of daily physical activity, built environment perception, social capital and individual characteristic were obtained through network survey. The theoretical relationship between built environment and health of residents was established. Firstly, physical activity was used as the mediating factor. Using the method of multiple regression equation, this section studied the built environment factors that affected the traffic walking activity and leisure walking activity. This work has been published in the No. 3 of Vol. 11 of the journal "Sustainability" in 2019. Second, the study further discussed the influence of subjective perception of the built environment on moderate to vigorous physical activity of residents, as well as the influence path of the objective characteristics and subjective perception of the built environment on moderate to vigorous physical activity of residents. This work has been published in the No. 1 of Vol. 12 of the journal "Sustainability" in 2020. Third, the study took the self-rated health of residents as the explained variable and the built environment, subjective perception, social environment and other factors as the explanatory variables to research the impact of built environment on health of residents. Finally, through the method of structural equation model, this dissertation discussed the influence path of

built environment on health of residents based on physical activity. In the whole process of the study, the different factors and paths of the built environment on the health of male and female were discussed. The conclusions were as follows.

First, the built environment had an influence on the traffic walking activity and leisure walking activity. Improving mixed use of land and increasing commercial facilities, living service facilities and catering facilities can promote the traffic walking activity of residents. The community with high facilities density, convenient sports facilities and green park are more conducive to promoting residents' leisure walking activity. Community safety, community life satisfaction affected the leisure walking activity of residents. Individual characteristics had no effect on traffic walking activity, but had significant effect on leisure physical activity. The built environment acted on moderate to vigorous physical activity through subjective perception. Security perception played a mediating role.

Second，built environment, subjective perception and social environment had an influence on residents' self-rated health. These factors included land use mixedness, convenience of life service facilities, convenience of sports facilities, convenience of bus stops, environmental quality perception, environmental facilities perception, community safety, community life belonging, community management satisfaction, length of medium and high intensity physical activity and love of sports. Building environment factors can directly affect the health of residents, but also through community security, social capital affect physical activity, and then affect health.

Third, it is found that the influence of built environment factors on male's and female's physical activity and health were quite different. For male and female walking activities, some influencing factors had opposite effects, and some influence factors had significant differences. For male, the objective characteristics of built environment had less influence on subjective perception. but it can directly affect the moderate to vigorous physical activity. Road connectivity and sports facilities accessibility can affect physical activity through community safety, and then affect health. It can also directly affect physical health through the role of social capital. For female, the objective characteristics of built environment had an influence on subjective perception, but not directly affected the physical activity. The intermediary role of community safety was significant.

Key Words: Built Environment, Physical Activity, Health, Community Safety, Social Capital, Multiple Regression Analysis, Structural Equation Model

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Contents

Chapter 1 - Introduction

1.1 Research Background

Rapid urbanization had made great contribution to the development of the world economy, and also brought various "urban diseases" to human beings, which seriously threaten the health of urban residents. Non-communicable chronic diseases have replaced acute infectious diseases and become the primary threat to urban public health (WHO, 2009). According to the World Health Statistics 2017 released by the World Health Organization, 71% of global deaths were caused by non-communicable diseases, which account for 41 million people (WHO, 2017). Health has become a major issue affecting future economic and social development. As early as 1946, the World Health Organization gave a definition of health. Health is not simply the absence of disease, but a state of complete physical and mental health and social well-being.Human mental health can not be ignored. In 2013, the UN Secretary General reported on the global suicide prevention day that there were 340 million people suffering from depression all over the world.

In order to cope with the severe challenges brought by the rapid urbanization process to human health, and to better solve the urban problems and comprehensively improve the health level of people, the World Health Organization put forward the new concept of "Healthy City" in 1984. In 1994, World Health Organization defined that “Healthy City” should be a city that constantly develops and improves the natural and social environment, and constantly expands social resources, so that people can support each other in enjoying life and giving full play to their potential. A healthy city is an environmentally friendly city. In 1986, the World Health Organization first proposed a global strategic action in Europe “Healthy City Project”. The Healthy City Project is a dynamic plan. After more than 30 years of development, the project has evolved into a long-term international project aiming to introduce health and its connotation into the urban decision-making process (WHO, 2003). Healthy city is a whole composed of healthy people, healthy environment and healthy society. Cultivating healthy people is the starting point and foothold of healthy city construction.

As early as 1848, the United Kingdom promulgated the public health law to improve the urban environment, which means that the urban planning department began to pay attention to the built environment and public health. Since 1950, many social problems caused by the low-density spread of American cities had made people connect the built environment with public health again. In 1966, the U.S. Congress

passed the “National Health Planning Act” and carried out a research project on the relationship between health facility planning and urban planning. In 1986, “American Journal of Health Promotion” put forward the concept of “Health Promotion”, which referred to “a kind of science and art that can help people improve their way of life and achieve the ideal health effect”. Health Promotion is a public health concept, which is transferred from disease-centered to health-centered, from the intervention of disease to the intervention of risk factors affecting disease. In 1995, the Western Pacific Region Office of the World Health Organization published the “New Horizon of Health”, which pointed out that Health Promotion means that individuals, together with their families, communities and countries, take measures to encourage healthy behaviors and enhance people's ability to improve and deal with their own health problems. Health promotion is the core strategy of the second global health revolution, which focuses on the behavior change and environment change of individuals and groups. In 2003, two American journals published a special issue on built environment and health respectively. All these showed that the significance of the built environment for health had been recognized by the academic mainstream.

In 2005, the World Health Organization revised the definition of health promotion, and proposed that it is “a process of making people enhance their control over health and surrounding environment, so as to improve health”. Health promotion mainly involves five areas of activity, one of which is to create a supportive environment. Establishing a healthy supportive environment is one of the important goals of health promotion. The intervention of health promotion is the main means to create a material and social environment to support health, to promote people's behavior change and to establish a healthy lifestyle. In 2008, the Federal Department of Health and Human Services issued the “Physical Activity Guidelines Advisory Committee Report” and the “Physical Activity Guidelines for Americans: Be Active, Healthy, and Happy” to provide different age groups with information on the types and intensity of physical activity required for health, as well as relevant suggestions. At the local government level, in 2010, the New York City Government began to advocate the promotion of physical activity and health through urban planning and design, and issued “Active Design Guidelines”. In the same year, the United States Department of Health issued “Healthy People 2020”. In 2018, the “U.S. Physical Activity Guide” was issued.

In China, the rapid industrialization, land expansion and economic oriented development mode made great changes in the built environment, land use and spatial quality of the city, and also had a huge influence on urban public health. According to the “Report on Nutrition and Chronic Diseases of Chinese Residents (2015)”, from

2002 to 2012, the obesity rate of Chinese adults increased from 7.1% to 11.9%, and the overweight rate increased from 22.8% to 30.1%. In 2019, data from the China Health Commission showed that the death toll that caused by chronic non communicable diseases accounted for 88% of the total. Xiang et al. (2012) pointed out that the mental health problems of Chinese residents are also very prominent. All of these pose severe challenges to urban health, which the Chinese government attaches great importance to. In 1989, China began to carry out “Sanitation City” creation activity. In 1996, Shanghai, Beijing, Chongqing and Haikou became pilot areas for Healthy City in China. After SARS in 2003, China's healthy cities had entered the stage of comprehensive development. In 2016, General Secretary Xi Jinping stressed the importance of "integrating health into all policies" and issued a call for building “Healthy China”. In October of the same year, the Chinese government issued the “ ‘Healthy China 2030’ plan outline”, which formally proposed that the construction of healthy cities and healthy villages and towns should be taken as an important starting point to promote the construction of Healthy China, and health should be integrated into the whole process of urban and rural planning, construction and governance. In October 2017, the Chinese government proposed "Implementing Healthy China Strategy". Healthy China and Healthy City had become national strategies. In order to deal with the threat of urban development to public health, it is very important to reconstruct a built environment that is conducive to physical activity and health.

As a highly integrated and complex giant system, ensuring the public health and sustainable development of a city is one of the important goals of urban planning. Maantay (2001) called on the urban planning field to fully understand and evaluate the potential influence of planning or construction projects on public health, and the public health field must also understand the decision-making of urban planning or land use planning. The organic combination of urban planning and health fields' respective professional advantages is conducive to jointly coping with chronic diseases and health problems in urban development.

One of the core issues of urban planning is to explore the performance and formation mechanism of urban lifestyle. The research on urban space has also shifted from focusing on material forms in the early stage to analyzing the economic, political and behavioral processes of urban problems and specific spatial forms(Leitaer, 1989). As one of the important factors to promote physical activity and health, the built environment is an important entry point for urban planning to actively intervene in health (Lu and Tan, 2015). Due to the comprehensive influence of specific socio economic conditions and personal use patterns, the influence mechanism of built

environment on people's health is relatively complex (Diez-Roux and Mair, 2010). It is difficult to establish a direct relationship between the built environment and health, which is usually studied through the behavior carrier as an intermediary element. At present, the research dimensions concerned by North America, Europe and Australia mainly involve physical activity, social interaction, eating behavior. Residents' health activity behavior is an important form to represent the quality of life of residents. Its interaction with the specific environment and spatial characteristics of residents' health activity behavior has become a new important field of urban planning research(Kwan, 2004; Miller, 2004).

The physical activity behavior of residents is not only affected by the built environment, but also by the social environment and socio-economic conditions of the residents. How to control the socio-economic characteristics of the residents and identify the impact path between built environment and residents' health can truly understand the interaction between built environment and physical activity.

Based on the interdisciplinary study of urban planning and behavioral geography, this dissertation analyzed the physical activity behavior of individuals in different spatial conditions according to the interaction between human and space， and further analyzed the complex relationship between human health and built environment. Carry out the discussion on the influence path of the built environment on physical activity and health, consider how to optimize the urban physical environment and social environment to increase the health activity behavior of residents, put forward the space design suggestion of health promotion.

1.2 Research Purpose

Compared with the passive coping medical technology, the purpose of building environment optimization is to create a living environment conducive to physical activity and balanced diet through the space policy of active intervention. It has many advantages, such as the long-term effect, the universality of benefiting people, and the economy of social cost (Loon and Frank, 2011). Therefore, at the time of health crisis caused by urban sprawl, whether and how the built environment affects public health has become the common focus of health geography, urban and rural planning and preventive medicine research (Mitchell, 2012). The impact mechanism of urban built environment on health of residents is complex. Only by defining the influence mechanism of the built environment on health of residents in theory， we can provide effective strategies for healthy urban planning.

Chinese cities has their own characteristics, such as high-density and

high-intensity development of the built environment and a high proportion of public transport utilization. These are obviously different from the western countries. The research focused on Fuzhou City, Fujian Province, China. From the perspective of residents' behavior activities in the micro spatial scale, the PhD research aimed to the relationship between urban community built environment and residents' health, and its impact mechanism. Through this research, we try to achieve the following goals:

1. The quantitative relationship between building environment and individual healthy physical activity behavior is established. The relationship between building environment and different types of physical activity behavior is studied. And the internal mechanism of building environment influencing residents' activity behavior is studied.

2. From the perspective of physical activity, this dissertation studies the relationship and mechanism of the impact of built environment on health, and explores the intermediary role of social capital and community security in the process of influence.

3. Analyze the difference of the impact of the built environment factors on the physical activity behavior and health of male and female, identify the main factors affecting the physical activities and health of male and female in the built environment and the influencing path.

1.3 Literature Review

Built environment refers to man-made environment for human activities, including buildings and places built by people and the environment changed by people (Handy et al.,2002). It is composed of a series of elements such as land use, traffic network and space design (Frank et al., 2005). Physical activity is characterized by energy consumption produced by skeletal muscle contraction. Regular physical activity can control blood pressure, improve sleep and improve insulin sensitivity (US HHS, 2018). Sedentary behavior increases the risk of obesity, diabetes, cardiovascular disease (Thorp et al., 2011), and dyslipidemia (Zhou et al., 2017). It was estimated that physical activity not up to standard results in 6% of coronary heart disease, 7% of diabetes mellitus and 10% of premature death in the world (Lee et al., 2012). Modern health concept includes physical health, mental health, moral health, etc

1.3.1 The impact of built environment on physical activity and health

At the end of the 20th century, Cervero and Kockelman (1997) took density, diversity and design as the main analysis elements of traffic environment, and put forward the famous 3D model. Density includes population density, employment

density, land development intensity, etc. The diversity is usually evaluated by the entropy index of various land use, or the Hersheman-Hefndale coefficient. The design dimension includes not only the block scale and road accessibility at the macro level, but also the sketch design and street comfort at the micro level (Ewing et al., 2015). On the basis of 3D, Ewing and Cervero (2001) added two dimensions of destination accessibility and distance to transit to form the 5D dimension of evaluating built environment. The former can be measured by the distance to CBD and the accessibility of facilities; the latter can be reflected by the distance to metro station and bus station or their density.

From the influence of urban density: high density compressed the space-time distance between various destinations, creating conditions for green travel and increased physical activity (Cao and Fan, 2012). On the contrary, the stronger the trend of the spread of the built area, the longer the commuting time, the obvious obstruction of walking behavior, and the increase of vehicle mileage per capita. This led to a continuous decrease in moderate to vigorous physical activity(short for MVPA) (Lopez-Zetina et al., 2006), and the significant increase of body mass index (short for BMI), obesity, hypertension, heart disease, diabetes and other morbidity (Ewing et al., 2003, 2014; Joshu et al., 2008; Kelly-Schwartz et al., 2004). For example, for every 1% increase in the spread index of American metropolitan areas, the risk of overweight and obesity will increase by 0.2% and 0.5% respectively (Lopez et al. 2004). It had also been pointed out that high density only affected the walking behavior and health status of the vulnerable groups such as the unemployed, retirees and poor health, but not significantly affected the rest of the population (Forsyth et al., 2009). In contrast, the survey of metropolitan areas in the United States showed that, due to the fact that too high density was easy to cause physical and mental stress and insecurity, residential density had an adverse effect on self perception of overall health status (Kelly-Schwartz et al., 2004). However, in Greece, the negative effect of high density had also been found (Chalkias et al.,2013). Some scholars in China thought that high density was not good for health. For example, Sun et al. (2016) believed that residents living in communities with high density and facility accessibility had a high probability of overweight. Zhang et al. (2018) believed that the utilization of high density soil had a negative influence on the overall health of residents.

From the influence of diversity: land function mixing had positive significance for increasing physical activity and promoting physical health. The findings were generally robust in various studies. The diversified spatial environment in a small scale enriched the activity, enhanced the safety of residents and stimulates the vitality

of the city (Feng et al., 2010). The study of Atlanta showed that the mixed degree of land functions had a significant influence on residents' travel patterns. If you increase your driving time by one hour a day, your obesity rate will be increased by 6%; if you increase your walking time by one hour a day, your obesity rate will be reduced by 4.8% (Frank et al., 2004). Lathey et al. (2009) also believed that a single function will increase the dependence of citizens on mobile travel. Therefore, for the prevention of chronic diseases, it was more important to provide all kinds of non residential functions than whether the community location is located in the city center.

From the perspective of the impact of road network design: due to more traffic accidents and serious air pollution in the main roads, the adjacent high-speed roads and main roads were not conducive to the development of sports activity and green travel, resulting in the high incidence of obesity in the surrounding communities (Yu, 2015; Zhao, 2014; Joshu et al., 2008; Giles-Corti et al., 2003). If paves the sidewalk, sets the non motorized lane and installs the street lamp in the road system, it will help to promote the traffic microcirculation and increase the physical activity of the residents, and then play the role of inhibiting the chronic disease (Sallis et al. 2009; Joshu et al.,2008). However, some studies had found that the influence of land use mixedness and road network structure on public health was not obvious among women and ethnic minorities (Frank et al. 2008). It was not significant in the suburbs with low urbanization rate (Wang et al. 2013). Their influence on BMI was different in different cities (Pouliou and Elliott, 2010).

From the perspective of the influence of destination accessibility and public transport accessibility: a large sample survey of 11 countries around the world showed that the accessibility of low-cost recreational facilities and bus stops was positively correlated with physical activity (Samimi et al. 2009). Increasing public facilities such as parks and stadiums can effectively reduce the incidence of obesity and chronic diseases. It was because of the spatial inequality in the accessibility of these facilities that the obesity rate in low-income and minority communities was on the high side (Xu et al., 2015; Gordon-Larsen et al., 2006; Giles-Corti et al., 2003). Studies in London and Marion County had also confirmed that public entertainment places or green open spaces around families will provide places for physical exercise, which can effectively control the rapid rise of BMI among teenagers (Gilliland et al., 2012; Bell et al., 2008). As cultural and commercial facilities created more opportunities for people's activity, they can significantly reduce the risk of obesity, metabolic disorders, diabetes, hypertension and heart disease (Lattey et al., 2009). However, there was a significant negative relationship between bus station density and subway station density and BMI (Rundle et al., 2007). The use of public transport also had positive

significance for self-rated of health of residents, which was related to the accelerated calorie consumption of public transport travel (Samimi et al. 2009).

Other studies had focused on the influence of composite indices. It was found that the built environment suitable for walking had a significant positive influence on residents' green travel frequency and moderate to vigorous physical activity. This made people in walking friendly communities had lower BMI and less overweight probability (Saelens et al., 2003; Doyle et al.,2006), and more reasonable diastolic and systolic blood pressure ranges (Li et al. 2009). However, according to the prevalence of hypertension, diabetes, self-rated of health and doctors' evaluation, walking friendly environment only had a significant influence on long-term residents. This suggested that the effect of urban built environment on physical activity and body shape may be directly revealed, but in terms of chronic diseases and overall health, optimizing the effect of built environment needs a process of continuous accumulation (Doyle et al., 2006).

1.3.2 The impact of environmental perception on physical activity and health

Environmental perception is people's subjective feeling and psychological judgment on the surrounding environment and its changes, and it is the psychological basis of people's environmental behavior (Peng and Zhou, 2001; Lin et al. 2016). A large number of studies showed that residents' environmental perception had a more significant influence on self-rated health than the objective environment (Bird and Fremont. 1991; Kim, 2016). Leslie and Cerin (2008) conducted an empirical study in Australia, and found that there were correlations between many factors of neighborhood satisfaction (such as safety, walkability, social network, traffic noise) and mental health. Kim (2016) conducted an empirical study on Columbus City in the United States, established a comprehensive data set of environmental perception, objective environmental characteristics and self-rated of health, and found that walking friendly neighborhood perception characteristics were significantly positively correlated with self-rated of health. Some scholars believed that subjective aesthetic perception had an effect on physical activity (Karmeniemi et al., 2018; Vojnovic, 2006; Humel et al., 2002). Zhang et al. (2019) believed that environmental quality perception, service facilities perception and sports and leisure facilities perception were related to health of residents to varying degrees.

1.3.3 The impact of built environment on social capital and social capital on health

Social capital refers to trust, norms and networks that facilitate collective action (Putnam, 2001), including structural social capital measured by network scale and

interaction frequency and cognitive social capital measured by sense of belonging and trust (Moore and Kawachi, 2017). On the one hand, increasing the scale of social networks, the frequency of community activity, and the sense of trust and belonging can stimulate mutual aid behavior, consolidate social norms, and then promote physical activity (Ho et al., 2018), and improve self-rated of health (Pinillos-Franco and Kawachi, 2018); on the other hand, social capital may make members more susceptible to unhealthy hobbies through group pressure (Villalonga-Olives and Kawachi, 2017).

The accumulation of social capital depends on the interaction opportunities and emotional attribution brought by humanized space (Kim and Kaplan, 2004). 85%, 75% and 60% of the studies confirmed the positive effects of destination accessibility, road accessibility and functional diversity on social capital, and the influence of population density remains controversial (Mazumdar et al., 2018). Long distance commuting, car dependence and store shopping caused by low density spread reduce social interaction opportunities (Putnam, 2001). However, there was no significant difference in social time between urban and suburban residents (Morris and Pfeiffer, 2017), and dense mixed population will hinder social capital formation (Putnam, 2001).

1.3.4 The impact of built environment and social capital on urban safety and urban safety on physical activity and health

The safety level of the city is deeply influenced by the built environment. At the hardware level, street eye theory advocated open space with mixed functions and accessible road network, so as to achieve the purpose of natural monitoring through space use (Jacobs, 1961). However, defense space theory advocated a single function closed space to eliminate the invasion of mixed people (Newman, 1972). At the software level, the broken window theory attributed the safety risk to the environmental disorder in the maintenance and management links such as public property damage, dim street lights, and garbage everywhere. It believed that the out of order signals will attract potential criminals and worsen the safety perception (Foster and Giles-Corti, 2008; Collins, 2016).

Urban safety is also affected by social capital. Social deconstruction theory had shifted from focusing on the negative effects of population heterogeneity and mobility to integrating social capital theory (Bruinsma et al., 2013), emphasizing that communities lacking trust, public participation and collective effectiveness will weaken informal social control, thus increasing insecurity and crime rate (Collins, 2016). In the UK, the influence of social capital on the sense of resident safety was

stronger than that of built environment (Lorenc et al., 2013).

The quantitative analysis of the existing empirical results showed that the physical activity quantity of low community crime rate and high sense of safety samples was 28% and 27% more than that of high community crime rate and low sense of safety samples respectively (Rees-Punia et al. 2018).

1.3.5 The impact of built environment and social capital on mental health

The built environment can affect mental health by influencing individual behavior and stress release (Giles-Corti et al., 2016; Araya et al., 2007). Green space provided a place for residents' sports activity and social communication, which helped to reduce their mental stress, restore their attention and energy, and promote their physical and mental health (Markvych et al, 2017; Dong and Qin, 2017; Melis et al, 2015; Maas et al, 2006, 2009). Community service facilities are important factors affecting mental health. For example, Gute et al. (2006) found that residents' dissatisfaction with social and entertainment facilities will reduce their mental health level. Liu et al. (2017) also found that the high accessibility of cultural facilities had a significant positive influence on the mental health and happiness of the elderly. In addition, the accessibility of medical, sports, public transport stations and other service facilities was significantly related to residents' mental health (Li et al., 2019; Tian et al., 2017; Chen et al., 2015). The higher the residents' satisfaction with the residential area, the better their mental health (Dong and Qin, 2017). This showed that the improvement of built environment can promote the formation of social relations among residents, improve the satisfaction of residents for the community, and promote the mental health of residents. In social capital, the level of residents' mental health was positively correlated with the number of types of social organizations and the proportion of frequent contacts among community residents. This showed that increasing community organization and increasing the frequency of communication can promote the level of mental health of residents.

Western researches believed that physical exercise can be used as the third intervention method besides drug therapy and psychotherapy. Aerobic exercise or anaerobic exercise can prevent or reduce depression, anxiety and other psychological symptoms (Brown et al, 2013; Jayakody et al, 2014). Not only that, physical exercise can also change personal physical conditions. Strong physique and beautiful line shape reshaped their charm and enhanced their self-confidence and self-efficacy psychologically (Elavsky, 2010).

1.3.6 The impact of built environment on health based on gender perspective

In the 1980s, feminist research on urban development and urban planning began

to enter the fields of geography and planning. It was to pay attention to how to treat the needs of male and female equally. (Hanson and Pratt, 1988). The density of residential area was negatively correlated with female's leisure walking(Inoue,et al., 2010), but positively correlated with male's walking(Sigmndova, et al., 2011). Facilities accessibility (Santtos,et al., 2008) and environmental perception promote female's physical activity(Kondo,et al., 2009). In Australia, studies had shown that traffic safety was negatively correlated with walking in male and positively correlated with female.(Humpel, et al., 2004). Intersection density and population density only had positive effect on female physical activity(Troped, et al., 2010). Compared with male, female's physical activity level was more easily affected by the surrounding environment.(Santtos,et al., 2008). There were differences in the effects of physical activity on male and female. But the research on built environment based on gender is not systematic.

1.4 Organization

The paper is divided into seven parts. The third, fourth, fifth and sixth parts are the core chapters.

In the first part, we introduced the research background, research purpose and literature review to support research ideas.

In the second part, we introduced the research area and data sources. The object of this study was Fuzhou, a city in Southeast China. Fuzhou was the political and cultural center of Fujian Province, a famous historical and cultural city in China, with a permanent population of 4 million. It was representative in Southeast China. The research data mainly came from two aspects. First, urban open data, such as POI data of various facilities, population density data, etc. Second, social survey data, we used the network to carry out a social survey on the healthy life of Fuzhou residents. The survey contents included community built environment, social capital, physical activity, physical health, mental health and individual characteristics etc.

In the third part, starting with the intermediary element of physical activity, the chapter researched the impact of built environment on residents' walking activity. The research adopted multiple regression analysis method to explore the different effects of built environment factors on traffic walking behavior and leisure walking behavior. Through the spatial data of density, mixing degree, facility accessibility, traffic convenience, facility design and sample behavior activity data within the 500m radius of the social survey sample, this chapter analyzed which built environment characteristics will affect the physical activity of residents and how much influence

they will have. The study also considered the influence of individual characteristics. Traffic walking was mainly affected by land use mixedness, commercial facilities, living facilities, catering facilities, green facilities, main road density and access road density. The leisure walking behavior was affected by POI density, green space facilities, sports facilities and other factors. At the same time, we found that the sense of community safety, the richness of sports facilities and the satisfaction of community life also had an influence on leisure walking. The impact factors of the built environment on the walking activity of male and female were different. The mixed function, the proportion of POI in living service facilities and individual travel mode all had an influence on male's and female's traffic walking activity, but the influence was just the opposite. The proportion of POI in catering facilities, commercial facilities and green space facilities only affected male's traffic walking. Road density only affected female traffic walking. Population density and community safety had an influence on male's and female's leisure walking activity, but the influence of population density on male's and female's leisure walking activity was just the opposite. POI density and community life satisfaction only affected male's leisure walking activity. Land use mixedness, commercial facilities, catering facilities and green space facilities only affected female's leisure walking activity. This work has been published in the No. 3 of Vol. 11 of the journal "Sustainability" in 2019.

In the fourth part, we introduced the environment perception factors to study the influence path of the subjective and objective factors of the built environment on the moderate to vigorous physical activity. Firstly, the influence of subjective perception on moderate to vigorous physical activity was analyzed by multiple regression equation. After controlling individual characteristics, POI subjective density, POI entropy index, environmental beauty, environmental cleanliness, convenience of commercial facilities and community safety all had an influence on moderate to vigorous physical activity. Then, using the method of constructing structural model equation, this chapter analyzed the influence path of objective characteristics, subjective perception and community safety on the moderate to vigorous physical activity, and discussed the intermediary effect of environmental subjective perception and safety perception. There were two paths. One was that the built environment acted on moderate to vigorous physical activity through subjective perception (environmental density perception and environmental facilities perception). Another path was that the objective characteristics affected the community safety perception through subjective perception (environmental density perception, environmental facilities perception, environmental facilities perception), and then affected the moderate to vigorous physical activity. Subjective perception and community safety

played an intermediary role in the influence path of built environment on physical activity. For male, the direct influence path of the built environment on the moderate to vigorous physical activity was obvious. At the same time, the built environment can also affect the moderate to vigorous physical activity through the sense of safety and convenience of facilities. The perception of environmental density had a direct influence on moderate to vigorous physical activity in male. The perception of environmental quality and convenience of environmental facilities affected the moderate to vigorous physical activity through safety perception. For female, the built environment influenced the moderate to vigorous physical activity through intermediary elements. The built environment affected the perception of environmental density, environmental quality and environmental facilities. Environmental quality perception and environmental facilities perception affected female's moderate to vigorous physical activity through influencing safety perception. This work has been published in the No. 1 of Vol. 12 of the journal "Sustainability" in 2020.

In the fifth part, we discussed the influence of built environment on self-rated health of residents. In this part, we expanded the built environment to three types: objective elements, subjective perception and social environment. This chapter used multiple regression equation model to research the independent influence of built environment on self-rated health of residents under the control of individual characteristics, and the influence after increasing subjective perception and social environment. The results showed that the objective characteristics of built environment, subjective perception and social environment had different influence degrees on self-rated health. The influence degree of subjective perception was disturbed by social environment. Mental state affected self-rated health of residents. The impact of built environment on self-rated health of male and female was not significant.

In the sixth part, structural equation modeling method was used to construct the theoretical relationship between the built environment and health of residents from the aspects of community built environment, social capital, physical activity, physical health and mental health, and to further explored its internal influence mechanism. There were five main paths. First, the built environment had a direct influence on physical health. Second, the built environment affected physical and mental health through physical activity. Third, the built environment affected physical activity, physical health and mental health through community safety. Fourth, the built environment affected the community safety through social capital, and then physical activity, thus affecting physical and mental health. Fifth, physical health promoted

mental health. The influence path of female was not different from that of the whole sample. For male, the built environment affected physical and mental health through community safety. In addition, the built environment affected physical health through social capital.

In the seventh part, we summarized the research conclusions of the doctoral dissertation, and pointed out the limitations of the research and the problems that will be solved in the future.

Chapter 2 - Research approach

2.1 Study area

The study area is Fuzhou. Fuzhou is located in East China, East Fujian, lower reaches of Minjiang River and coastal areas, across the sea from Taiwan. It is the political, cultural, scientific, educational and transportation center of Fujian Province, and an important city in Southeast China. The location of Fuzhou in China is shown in Figure 2-1. Fuzhou is located at 25°15' ~ 26°39' N and 118°08' ~ 120°31' E. it is a typical estuarine basin surrounded by mountains and rivers, with beautiful natural scenery. Fuzhou has Gu mountain in the East, Qi mountain in the west, Wuhu mountain in the South and Lianhua peak in the north. The terrain inclines from west to East. Minjiang River flows into the sea across the city. Fuzhou City covers a total area of 1786 square kilometers, of which the built-up area is 357 square kilometers. Fuzhou's central city has a permanent population of 4 million. See Figure 2-2 for the image of Fuzhou central city. Fuzhou has a comfortable climate, abundant sunshine, abundant rainfall, long summer and short winter. The annual average precipitation is 900-2100mm; the annual average temperature is 20-25℃.

According to the information on the government website, in 2017, the forest coverage rate of Fuzhou was 56%, the green coverage rate of the built-up area was 43.93%, and the per capita park green area of the urban area was 15.05 square meters. Fuzhou has a good ecological environment and won the title of "National Forest City". In the "Notice on the evaluation results of National Healthy City" issued by the National Health Office in 2018, Fuzhou ranked first in the construction of Healthy City in Fujian Province and 13th in China.

Fujian Province also attaches great importance to the construction of Healthy City. Fujian Province issued the "Implementation Plan of Healthy Fujian Action" in January 2020. In the plan, all-round intervention on health influencing factors was mentioned. They included national fitness, mental health promotion and healthy environment promotion.

Figure 2-1 The location of Fuzhou in China

Figure 2-2 Satellite image map of Fuzhou

2.2 Data source

The data of this study included social survey and open network data. The social survey data mainly came from the questionnaire survey conducted in the urban area of Fuzhou in 2017. This questionnaire adopted the way of network research. The questionnaire included personal information, community facilities, community communication, community satisfaction, eating behavior, physical activity, safety perception, physical health and mental health. After the completion of the questionnaire design, 2000 questionnaires were sent out by professional survey companies. After eliminating the questionnaires of home address, environmental assessment, personal health and other major information deficiencies, 1308 valid samples were finally obtained as the basic database of this study. After manual query and coordinate correction, obtained the spatial points of the residence of the interviewee (Figure 2-3). This study was based on the micro level of the community。 In order to make the built environment elements and physical activity in a unified analysis scope and avoid the uncertainty of geographical background (Troped et al., 2010; Kwan, 2012), the built environment elements take the 500m space around the sample as the research scope. This distance is basically in line with the community scope of residents' walking comfortable life circle (Figure 2-4).

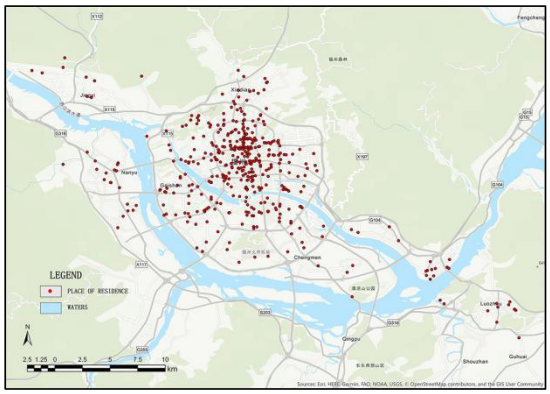

Figure 2-3 Distribution of sample residence

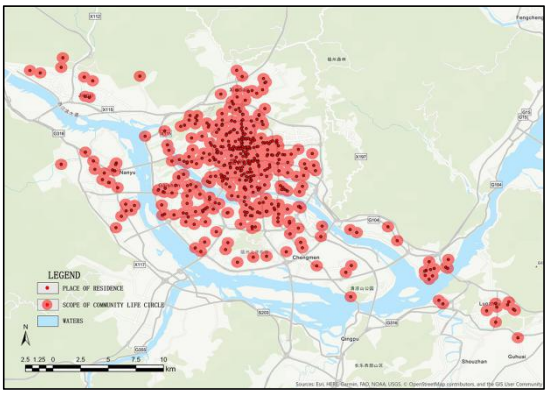

Figure2-4 Sample community life circle

In terms of individual characteristics. The average age of the respondents was 31, mainly in the 20-40 age group. This was mainly because the social survey adopted the way of network, and the older residents paid less attention to the network survey information. Male made up 60. 7%, 39.3% female. Married or cohabiting accounted for 64.83%, unmarried accounted for 35.17%. 61.01% of them were registered in Fuzhou and 38.99% were not registered in Fuzhou. 64.22% had higher education and 35.78% had no higher education. At the same time, the monthly income, housing property rights and community types of residents were also investigated. See Table 2-1 for details.

Table 2-1 Basic information of respondents

Category	Variable		Sample Size		Frequency
Individual Characteristics	Gender	Male	1308	794	60.70%
		Female		514	39.30%
	Average Age	31	1308	——	——
	Marital Status	Married	1308	848	64.83%
		Unmarried		460	35.17%
	Registered Residence	Fuzhou	1308	798	61.01%
		Nun Fuzhou		510	38.99%
Socioeconomic Condition	Monthly Income	2000 RMB and Below	1308	180	13.76%
		2000-4000 RMB		272	20.80%
		4000-8000 RMB		558	42.66%
		8,000 RMB and Above		298	22.78%
	Education	Junior Middle School and Below	1308	130	9.94%
		Senior School or Technical Secondary School		338	25.84%
		Bachelor or Senior College		742	56.73%
		Postgraduate and Above		98	7.49%
	Housing Property Rights	Home Ownership	1308	224	17.13%
		Rental Housing		1084	82.87%
	Community Type	Neighborhood Old Town	1308	154	11.77%
		Unit Community		138	10.55%
		Indemnificatory Housing		144	11.01%
		Commercial Housing		646	49.39%
		Villa District		62	4.74%
		Villages In The City And Others		164	12.54%

Public services and public transport facilities spatial interest point data was the data of Fuzhou City in 2017 downloaded from a map web site. These data included the geographical location of business facilities, catering facilities, life service facilities, sports and fitness facilities, green space facilities, and of bus stops. We imported POI

data into ArcGIS, and presented the spatial distribution map of various facilities in Fuzhou according to the spatial unit grid of 200 * 200m. Commercial facilities include supermarkets, convenience stores, hardware stores, pet stores, etc. (Figure 2-5). Life service facilities include hair salon, photo studio, laundry, computer maintenance, electric vehicle maintenance, etc. (Figure 2-6). Catering facilities include all kinds of restaurants, snack bars, etc. (Figure 2-7). Sports and fitness facilities include various fitness centers, yoga centers, activity centers, etc. (Figure 2-8). Green landscape facilities include various parks, cultural squares, etc. (Figure 2-9). See Figure 2-10 for the spatial distribution information of bus stops. In addition, the data of population density of each community and road network were obtained from the web site of Fuzhou government.

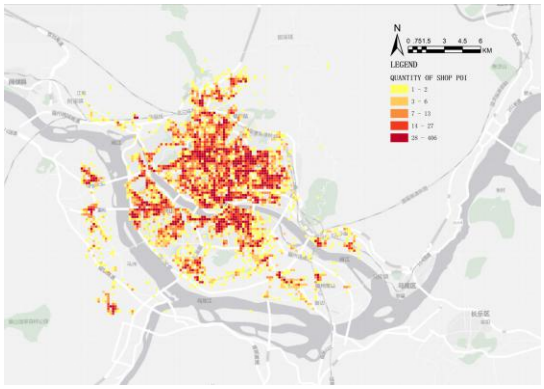

Figure 2-5 Distribution of commercial facilities

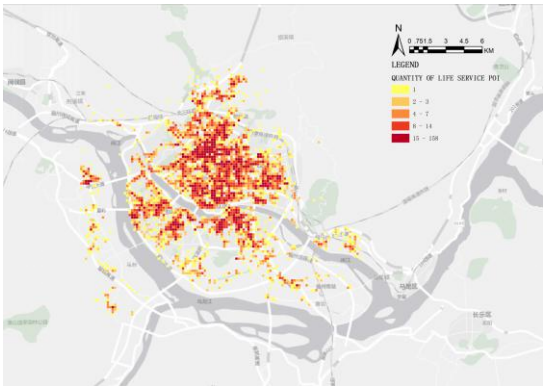

Figure 2-6 Distribution of living service facilities

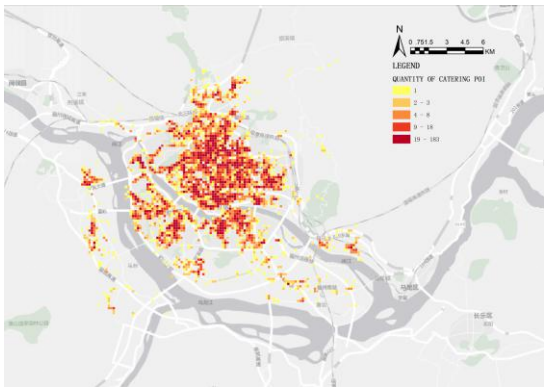

Figure 2-7 Distribution of catering facilities

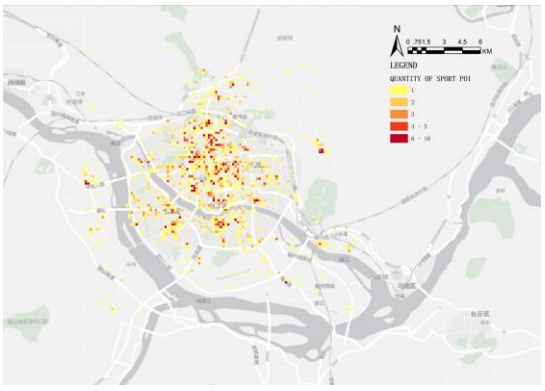

Figure 2-8 Distribution of sports facilities

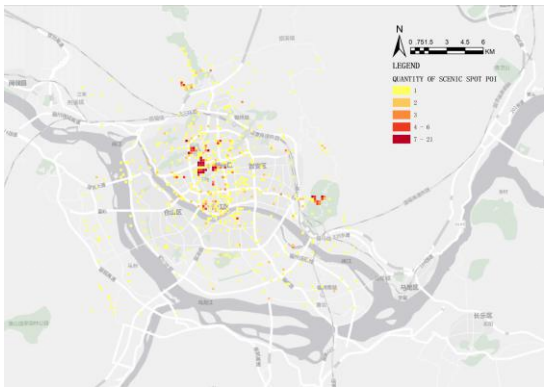

Figure 2-9 Distribution of green park

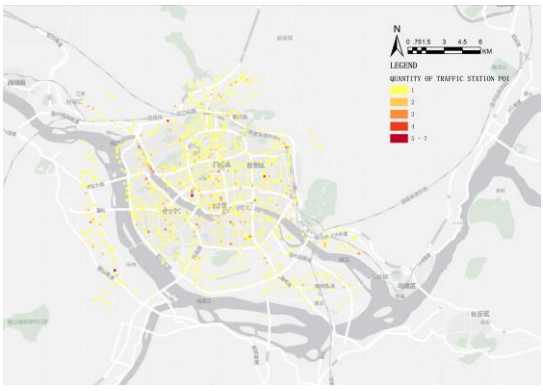

Figure 2-10 Distribution of bus stops

Chapter 3 The impact of the built environment on the walking activities

3. 1 Introduction

According to the research of the World Health Organization, many factors affect personal health together, among which heredity accounts for 15%, environment accounts for 17%, health service accounts for 8%, lifestyle and behavior accounts for 60%. A large number of scientific evidences proved that lack of physical activity was an important risk factor for chronic non communicable diseases besides unhealthy diet, smoking and drinking. It was the fourth major cause of chronic non communicable diseases (including heart disease, stroke, diabetes and cancer) in the world. Three million people lose their lives every year (Bull, 2011). Now, this phenomenon is not only in developed countries, but also in developing countries. According to recent data, it was estimated that 60% of the world's population lacked the amount of physical activity needed to maintain health (WHO, 2009). According to the research of UK Health Department (2004), physical activity had significant effect on health from two aspects of prevention and treatment. Therefore, how to promote people's physical activity and encourage people to actively participate in physical activity had become the priority strategy of health promotion in most countries. At present, the research on the impact of built environment on the physical activity was a hot topic in many countries (Sundquist et al., 2011; Troped et al., 2010; Davison and Lawson, 2006)

Physical activity is generally divided into occupational, traffic, housework and leisure (Wang and He, 2008). This study focused on physical activity of transportation type and leisure type. Walking, as one of the most basic forms of physical activity to promote people's health, is an effective way to prevent and treat chronic diseases such as obesity, cardiovascular and cerebrovascular diseases, type II diabetes, bone and joint diseases and mental diseases (Xiang et al., 2009; Saelens and Handy, 2008). In the study of the relationship between built environment and physical activity, Susan et al. took walking as the research object (Berke et al. 2007; Susan et al., 2005). Owen et al. (2004) studied the total amount of leisure walking. Some Chinese scholars had also studied the relationship between walking volume and blood pressure level, triglyceride level, body weight, BMI, waist circumference, waist to hip ratio and other indicators, confirming the promotion effect of walking on health (Li et al. 2012).

Existing research on physical activity showed that the planning and design of

built environment, especially for land use and transportation system, can significantly affect the spatiotemporal behavior of residents and guide the transformation of traffic behavior and physical activity (He et al., 2014). Vojnovic (2006) found that convenient community connection and appropriate distance can promote residents to choose more healthy transportation modes, such as walking and cycling. Handy et al. (2002) believed that density was an important built environmental feature affecting physical activity. Frank and Pivo (1994) thought that the density mainly affected the traffic walking activity. Forsyth et al. (2007) thought that density had not necessarily affect leisure physical activity. The higher the general density, the smaller the commuting distance between people's living, working, shopping and other destinations, and the lower the dependence on motor vehicle traffic (Cervero and Kockelman, 1997). With regard to the relationship between population density and traffic physical activity, most studies had found that community population density may be positively related to the total amount of walking and cycling of residents (Frank et al., 2007; Braza et al., 2004). However, some studies had found no correlation between the two (Pont et al., 2009). These studies were from the United States, where the relative population density was low.

It was believed that scientific land mixed use can encourage people to walk and bike more (Stock et al., 2012; Owen et al., 2010). Compact land development model can also enhance the vitality of street life and the supporting capacity of neighborhood business, thus promoting residents' walking (Feng, et al., 2010). Learnihan et al. (2011) thought that land mixed use had the greatest influence on traffic walking activities, followed by other forms of physical activity. McCormack et al. (2010) pointed out that the public space is conductive to increasing traffic walking and leisure physical activity. For commercial facilities (Handy, 1992; Humel et al. 2004), entertainment facilities (Handy et al., 2006, 2008), public welfare facilities (Cao et al., 2009; Handy et al., 2006, 2008), bus stations (Lee et al., 2009; Brown and Werner, 2007) and other basic facilities, it had obvious effect on traffic physical activity. The accessibility of public spaces such as parks (Powell et al., 2003) and green spaces (Coombes et al., 2010) can increase walking physical activity. The correlation between street network connectivity and physical activity was not clear. Frank et al. believed that improving street connectivity can promote physical activity (Boarnet et al., 2008; Nelson et al., 2006; Frank et al., 2004). However, Handy et al., believed that improving street connectivity can inhibit physical activity and may not affect physical activity at all. (Larsen et al., 2009; Wells and Yang, 2008; Handy et al., 2005). Hou et al. (2010) believed that road density was not related to walking, cycling, jogging (male) or negatively related (female).

The street scale, pavement, greening and sketch facilities played a positive role in pedestrian activities (Boarnet et al., 2011; Borst et al., 2009; Krizek and Johnson., 2006; Nelson et al., 2006). A new study of the Czech United Nations found that when residents perceived the comfort of their surroundings, their daily steps will increase (Sigmundová et al., 2011). Inoue et al. (2010) also found that residents were more likely to walk in their leisure time when they perceived that the surrounding environment was beautiful. However, the Belgian study found that the residents' cognition of the surrounding environment beautification was negatively correlated with the physical activity level measured by the accelerometer(Van Dyck et al., 2011). Hoehner et al. (2005) also proved that the surrounding environment beautification measured by the subjective and objective was negatively correlated with the traffic trip and physical activity.

The environment with better safety perception was more conducive to physical activity (Inoue et al., 2010; Nelson et al., 2006). Other studies had found that safety perception had a more significant influence on female (Humel et al., 2004). However, a Portuguese study showed that the public safety of the surrounding environment was not related to the level of physical activity (Santos et al., 2008).

Considering the differences of institutional environment and form, it is difficult to direct the healthy urban planning of developing countries based on the theoretical results of European and American countries. In this study, taking Fuzhou City as an example, we integrate social survey, land use, road network, spatial interest points and other data to explore the influence of built environment on walking physical activity at the community scale. The study observed the impact of built environment on traffic and leisure walking activity, and compared the differences between male and female.

3.2 Method and variables

3.2.1 Method

Firstly, all kinds of POI data within the 500m buffer range of the survey samples were extracted by ArcGIS software and imported into Excel software for data processing. Then with the help of SPSS software, the physical activity characteristics of the survey samples and the built environment elements data were described and counted. Finally, through the establishment of multiple regression model to calculate the correlation coefficient, analyzed and compared the influence degree of various factors.

The multiple regression analysis is a statistical quantitative analysis method, which mainly studies the quantitative change of variables. It can help people

accurately grasp the influence degree of variables by one or more other variables. The first step of regression analysis is to determine which things need to be explained, that is the explained variables (Record as y). Which things are used to explain other things, that is, explanatory variables(Record as x). Multivariate linear regression analysis is to establish the regression equation of y on x, which is used to reveal the linear relationship between the explanatory variables and other explanatory variables. Multiple linear regression mathematical model as formula 3-1.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p + \varepsilon \qquad \textbf{(Formula 3-1)}$$

This is a multiple linear regression model with P explanatory variables. It shows that the change of the explained variable y can be explained by two parts. First, the linear change of y caused by the change of p explanatory variables, i.e. $y=\beta_0+\beta_1x_1+\beta_2x_2+\ldots+\beta_px_p$. Second, the change of y caused by other random factors, i.e. ε。 β_0、β_1、β_2...β_p is the location parameter of the model, which is called regression constant and partial regression coefficient respectively. ε is called random error, which is also a random variable. If the expectation is found on both sides of formula 3-1, there is multiple linear regression equation 3-2.

$$\mathrm{E}(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p \qquad \textbf{(Formula 3-2)}$$

3. 2. 2 Variables

3. 2. 2. 1 Explained variable: walking activity

The study used walking to reflect the physical activity of residents. Two explanatory variables, the time length of traffic walking activity and the time length of leisure walking activity, were used to observe the residents' physical activity of traffic type and leisure type. Traffic walking refers to purposeful walking, including going to working, school and shopping. Exercise and stroll are leisure walking activities. The walking activity data was collected in the form of hours by using the length of walking time per week described by residents themselves.

According to the survey, 29.81% of the respondents did not spend more than 2.5 hours of traffic walking activity per week (0.5 hours a day, 5 days). 66.15% of them used private cars, taxis or e-bikes. 53.06% of the respondents did not walk more than 3.5 hours of leisure walking activity per week (0.5 hours per day, 7 days). When all the walking time was added up, 22.71% of the respondents still walked no more than 3.5 hours per week (0.5 hours per day, 7 days). The walking time of respondents is shown in Figure 3-1.

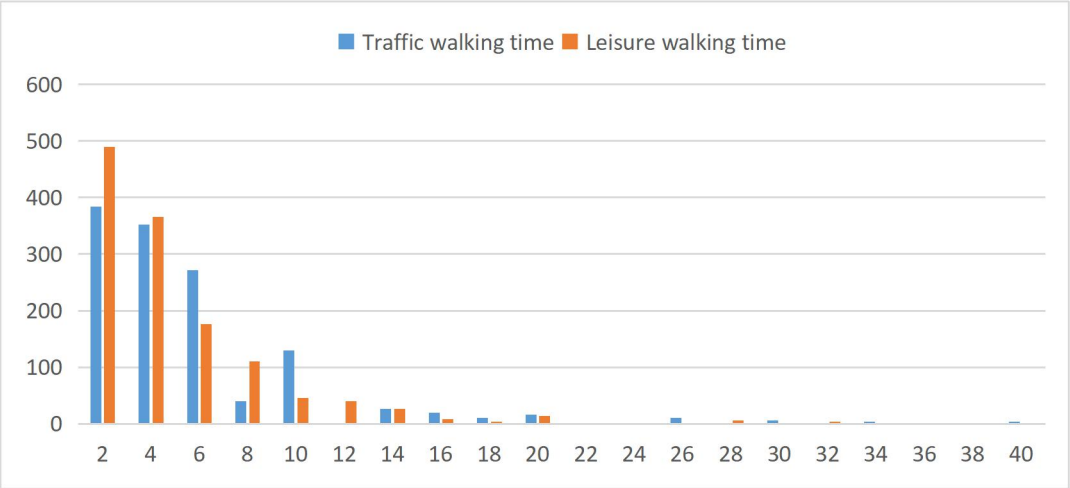

Figure 3-1 Length of walking activity per week

3. 2. 2. 2 Explanatory variable

The explanatory variable is the objective characteristic element of built environment, and the objective evaluation method of GIS and the subjective evaluation method of interviewees are used. The objective characteristics of built environment refer to the 5D dimension built environment elements proposed by Ewing.

The permanent population density and the facilities POI density were selected for the built environment density. The data of community resident population density was the public data of the government web site, which was the population density of the subdistrict where the sample lives. POI density refers to the spatial distribution of public service facilities in a certain region. This data came from open network data. Through the connection analysis of ArcGIS software, we can evaluate the social and economic activity compactness of the community.

The degree of mixing is quantified by the Herchmann-Hefndale coefficient of land-use properties. The coefficient close to 0 indicates that the land-use properties are diverse, and close to 1 indicates that the land-use properties are relatively single. The main road network density and branch road density are used to reflect the road shape design. The proportion of the number of commercial facilities, living service facilities, catering facilities, green space facilities and sports facilities in the investigator's buffer zone to the total number of facilities POI reflects the accessibility of the facility.

The distance to public transport is observed by the number of bus stops within the investigator's buffer zone. The more the number, the more convenient the public transport is. The study also chose individual travel mode to explore the impact of physical activity on transportation. The value of individualized motor travel is 1, including car and taxi travel. Public transport travel is assigned as 2, including bus,

subway and other public transport. The value of individual non motorized travel is assigned as 3, including walking and non motorized travel. These three levels reflect the physical strength of residents in different ways of travel. 1 is the weakest, 2 is the second, and 3 is the most healthy way to travel. The proportion of people using private cars, taxis and electric bikes is 48.70%, the proportion of people using public transport is 36.47%, and the proportion of people using walking and cycling is only 14.83%. We can see that Fuzhou is still highly dependent on private transportation. Due to the long distance, the ratio of walking and cycling is low.

In this study, the design quality of physical environment facilities is reflected by the richness of sports equipment. Community life satisfaction and community safety reflect community social environment perception. These explanatory variables are evaluated by subjective evaluation method. See table 3-1 for the details of variables.

3.2.2.3 Control variable

The individual characteristics of the respondents will affect their physical activity, and the study will control the relevant individual variables together. The individual characteristic variables selected in this study include age, gender, education, marital status and monthly income. In view of the problem of living self selection, we choose to control the degree of love for sports.

Table 3-1 Statistics description of variables

Variables	Value Description	All Samples		Male		Female	
		Mean Value	S.D.	Mean Value	S.D.	Mean Value	S.D.
Explained Variable							
Traffic Walking Time	Unit: hour	10.01	6.46	11.66	5.45	7.46	3.22
Leisure Walking Time	Unit: hour	4.46	6.45	4.73	7.13	4.03	5.08
Explanatory Variable							
Population Density	Unit: 10,000 people/km^2	1.55	1.24	1.45	1.19	1.72	1.30
POI Density	POI quantity per square kilometer in buffer zone, unit: 10000 / km^2	0.05	0.04	0.05	0.05	0.06	0.05
Land Use Mixedness	HH=$\sum_{i=1}^{16}(S_i - x_i)^2$, S_i is the proportion of class i land area within 500m radius around the residence, x_i is the proportion of class i land area in the central urban area	0.41	0.26	0.40	0.26	0.42	0.25
Main Road Network Density	Unit:km/km^2	11.02	3.18	10.87	3.25	11.26	3.06
Branch Network Density	Unit:km/km^2	7.84	2.66	7.78	2.61	7.94	2.73
Proportion of Commercial Facilities POI	Unit：%	30.00	21.50	29.95	21.90	30.09	20.89

Proportion of Living Service Facilities POI	Ditto	14.06	10.34	13.79	10.35	14.47	10.34
Proportion of Catering Facilities POI	Ditto	20.48	15.32	19.99	15.60	21.24	14.86
Proportion of Park Green Space POI	Ditto	1.56	5.31	1.57	5.61	1.57	4.81
Proportion of Sports Facilities POI	Ditto	1.94	2.93	1.94	3.03	1.95	2.80
Number of Bus Stops	Unit：Number	3.17	2.86	3.04	2.90	3.37	2.80
Traffic Trip Mode	Individual mobility=1；Public transportation=2；Individual immobilisation=3	1.62	0.87	1.62	0.88	1.61	0.85
Richness of Sports Facilities	Very scarce=1 to Very rich=5	3.60	1.04	3.60	1.08	3.60	1.00
Community Safety	Very worried=1 to Very not worried=10	7.14	2.10	7.17	2.07	7.09	2.17
Community Life Satisfaction	Very dissatisfied=1 to Very satisfied=10	6.82	1.92	6.69	1.93	7.03	1.90
Control Variable							
Gender	Male=0，Female=1	0.39	0.49	-	-	-	-
Age	Unit：year	31.32	9.04	31.82	9.05	30.54	8.98
Marital Status	Unmarried=0，Married=1	0.65	0.48	0.63	0.48	0.68	0.47
Education	No higher education=0，Higher education=1	0.46	0.50	0.39	0.49	0.58	0.49
Monthly Income	Unit：RMB 10000	0.78	3.97	0.66	0.54	0.96	0.63
Love Sports	Very loathsome=1 to Very fond =4	2.79	0.74	2.93	0.70	2.57	0.74

3. 3 Results

3. 3. 1 Influence of built environment on traffic walking time

Model 1 mainly studied the built environment factors that affected traffic walking time after controlling the personal characteristic variables. In Model 2, based on Model 1, the variables of individual travel mode and community safety were added for regression analysis.

From the perspective of Model 1 and Model 2 (Table 3-2), there was a significant negative correlation between traffic walking activity and land use mixedness ($P < 0.01$). This showed that the mixed degree of urban functions had a positive role in promoting the traffic pedestrian behavior of residents. The community with mixed functions was conducive to enhancing the vitality of street life and the support of neighborhood business. The more likely residents were to choose walking to complete necessary activity. This part was similar to the relevant research results (Inoue et al., 2010; Kondo et al., 2009; Hoehner et al., 2005; Saelen et al., 2003). The length of traffic walking was not related to the POI density and population density of

the community. This was different from the related research. This may be related to the urban characteristics of eastern China. The population density and urban construction density of eastern China are both large, and the urban scale is also large. For example, the urban population of Fuzhou has reached 4 million. The daily traffic distance often exceeds the walking distance range, so it is difficult to show the correlation between the density and the traffic walking activity.

In terms of the accessibility of built environment facilities, there was a secondary significant positive correlation between commercial shopping, life service Facilities and traffic walking time ($P < 0.05$), and there was a significant positive correlation between catering facilities, green park facilities and traffic walking ($P < 0.01$). The results showed that high density public service facilities help residents choose more walking behaviors. The increase of walking behavior helps to improve the health of residents.

From the perspective of road connectivity, there was a secondary significant positive correlation between urban main road density and traffic walking ($P < 0.05$). The greater the density of urban main roads, the more conducive to encourage residents to choose active transportation. This was consistent with some research conclusions (Boarnet et al., 2008; Nelson et al., 2006; Frank et al., 2004). At the same time, the results showed that the branch density was negatively correlated with traffic walking ($P < 0.1$). This was different from our research hypothesis. Of course, the current research conclusions had some controversy on street connectivity as a measure of improving physical activity.

From the perspective of personal characteristics, gender, age, higher education level and marital status had no significant effect on traffic walking behavior. Only monthly income traffic walking had a significant positive correlation ($P<0.05$). The higher the monthly income, the longer the traffic walking time.

After adding variables to Model 2, the results showed that the influence of built environment factors had little change with model 1. The influence of branch density became uncorrelated. The proportion of POI of commercial service Facilities decreased one level. Other elements had not changed. The newly added two variables had no significant effect on traffic walking. Traffic walking behavior is a necessary behavior of residents, and the influence of safety factors on behavior is very weak.

3.3.2 Influence of built environment on leisure walking time

Model 3 analyzes which elements of built environment have an impact on leisure walking activities. From the analysis results of Model 3, Leisure walking activities were affected by POI density ($P < 0.05$). The results confirmed that density is an

environmental factor for physical activity intervention. In the area with low density, people's life is more dependent on cars, resulting in a significant decline in physical activity, which may affect their health. Through the government's active intervention in urban construction density, compact urban development has a significant impact on promoting physical activity.

Land use mixedness, the proportion of commercial facilities, catering facilities and living facilities had no correlation with leisure walking time. This may be because when we distinguish traffic walking and leisure walking, we define leisure walking as aimless walking. Targeted shopping, catering and other activity are classified as traffic behaviors, so the accessibility influence of such facilities is not significant. However, sports facilities play an active role in promoting leisure walking activities ($P < 0.05$). The proportion of POI in green space Facilities was also correlated with leisure walking time ($P < 0.1$). It showed that the construction of sports facilities and green space is conducive to the development of leisure physical activity.

There was no significant correlation between street population density, main road density and branch road density and leisure walking time. This is also consistent with relevant research, and the relationship between density and leisure physical activity and overall physical activity is not clear (Forsyth et al., 2007). Generally, leisure walking takes place in the streets with pleasant scale. The main road is dominated by vehicles, so the density of the main road has no effect on the walking activity. In model 4, the branch density with a more pleasant scale had a certain influence on leisure walking activity. However, from the current results, there was a negative influence. We further observed the survey data and found that when asked "where do you usually choose to do physical exercise", 58.13% of the people choose to do physical activity in the residential area, and 17.92% choose to do physical activity in the professional gym. Our analysis is due to the fact that most of the physical activity places of Chinese residents are in residential areas. Chinese residential area model is relatively closed. If the surrounding roads are dense, the scale of residential area is small, and the places where residents can carry out physical activity are small, thus inhibiting the residents to carry out leisure walking activity.

In Model 3, age and education were negatively correlated with leisure walking. The older the residents are, the more concerned they are about their health, the stronger their willingness to exercise, so the longer their physical activity time is. The residents without higher education spent more time on leisure walking than the residents with higher education. We believe that the residents with higher education work longer, work under more pressure, and use more efficient sports, so the leisure walking time is shorter. Married or cohabiting residents had longer leisure walking

time. Stable marital status was conducive to promoting leisure physical activity. Gender and monthly income had no significant effect on leisure walking.

Model 4 added subjective perception elements to the built environment. The results showed that the influence of built environment factors had not changed. Community safety and community life satisfaction had a significant positive correlation ($P < 0.01$). Community safety perception will affect residents' willingness to carry out physical activity in the community. Building a safe community environment can promote physical activity, help reduce weight related chronic diseases and improve health. The more satisfied with the community life, the more willing the residents are to have leisure walking activity in the community. The abundance of sports facilities had a secondary significant positive correlation on leisure walking ($P < 0.05$). This variable was based on residents' subjective perception. This result was consistent with the objective analysis of POI proportion variables of physical facilities.

In Model 4, the control variable of sports loving degree was added. Compared with the passivity of traffic walking, the leisure walking activity is more active, so the individual's love for sports activities has a greater impact ($P < 0.01$). Every time the level of love is increased by 1 level, the time of leisure walking activity in the community will be increased by 1.169 hours every week. The influence of age was reduced by one level. There was a negative correlation between monthly income and leisure walking activity. This is consistent with the influence of education. But this was the opposite of the influence on traffic walking. We analyzed that the residents with higher income have higher work intensity and pressure, and pay more in work. The interest and intensity of leisure activity in the community are low.

Table 3-2 Multiple regression analysis results of all samples

	Traffic Walking Time				Leisure Walking Time			
	Model 1		Model 2		Model 3		Model 4	
	B	t	B	t	B	t	B	t
Population Density	-1.283	-0.862	-1.141	-0.764	-0.226	-1.053	-0.32	-1.553
POI Density	-38.096	-1.035	-42.853	-1.158	9.932**	2.251	11.482**	1.886
Land Use Mixedness	-68.336***	-4.267	-67.202***	-4.182	-2.623	-1.103	-2.176	-0.921
Proportion of Commercial Facilities POI	0.184**	2.064	0.169*	1.878	0.012	0.883	0.011	0.823
Proportion of Living Service Facilities POI	0.497**	2.125	0.476**	2.029	-0.006	-0.190	-0.002	-0.047
Proportion of Catering Facilities	0.704***	4.753	0.700***	4.717	0.018	0.859	0.011	0.551

POI								
Proportion of Park Green Space POI	3.617***	13.945	3.564***	13.577	56.415*	1.940	51.313*	1.778
Proportion of Sports Facilities POI					0.180**	2.277	0.175**	2.219
Main Road Density	1.460**	2.237	1.474**	2.253	-0.005	-0.053	-0.007	-0.071
Branch Density	-1.277*	-1.670	-1.259	-1.642	-0.169	-1.546	-0.160	-1.471
Number of Bus Stops	-0.168	-0.268	-0.105	-0.167				
Traffic Trip Mode			-1.123	-0.778				
Community Safety			1.224	1.527			0.465***	3.865
Richness of Sports Facilities							0.735**	2.096
Community Life Satisfaction							0.421***	3.408
Gender	-3.805	-1.471	-3.754	-1.450	-0.026	-0.067	-0.191	-0.497
Age	-0.062	-0.371	-0.094	-0.557	-0.072***	-2.988	-0.058**	-2.427
Marital Status	2.242	0.708	2.173	0.682	1.869***	4.116	1.632***	3.607
Education	-2.809	-1.109	-2.836	-1.112	-2.090***	-5.730	-1.981***	-5.472
Monthly Income	0.749**	2.372	0.761**	2.401	-0.071	-1.570	-0.076*	-1.686
Love Sports					1.196***	4.777	1.169***	4.615
B	6.822	1.042	7.534	0.939	8.105***	8.601	1.796	0.880
F	15.526		13.095		4.980		6.384	
Adjusted R^2	0.145		0.145		0.044		0.077	
Sig	0.000		0.000		0.000		0.000	

Notes: ***, **, * were significant at 0.01, 0.05 and 0.1 levels, respectively.

3. 3. 3 Comparative analysis of the influence of built environment on the walking time of male and female

After exploring the relationship between the built environment and walking activity through all the samples, we explored the differences between male and female in the influence of built environment on walking activity. Model 5 mainly analyzed the impact of built environment on male traffic walking. The results showed that there were different variables from the whole sample analysis, including main road density, individual travel mode and monthly income. The influence of main road density, monthly income on traffic walking activity changed from a significant correlation to no correlation. There was a significant negative correlation between individual travel patterns and traffic walking activity.

Model 6 mainly analyzed the impact of built environment on female traffic

walking. The results of female sample analysis were quite different from those of general sample analysis. The land use mixedness and the accessibility of facilities changed from promoting to restraining. The accessibility of commercial facilities and green space facilities was not related to traffic walking. And individual travel mode had a significant impact on traffic walking. This result was different from that of the whole sample, and also completely opposite to that of the male sample. From the perspective of individual characteristics, education had a significant negative influence, which was different from the results of all samples and male samples.

Model 7 analyzed the impact of built environment on male leisure walking. The variables that had changed the influence on leisure walking activity are security, community life satisfaction, POI proportion of green space facilities and sports facilities， population density. The influence of public safety and community life satisfaction decreased by one level. The big change was the accessibility of green space facilities and sports facilities. The influence of green space facilities on leisure walking changed from positive correlation to negative correlation. The influence of sports facilities had changed from significant correlation to non correlation. At the same time, population density had an impact on leisure walking activity.

Model 8 analyzed the impact of built environment on female leisure walking. Similarly, the results of female sample analysis were quite different from the results of overall sample analysis. There was no correlation between POI density and leisure physical activity. The influence of population density was positively correlated. This showed that male and female in leisure physical activity was the difference of density requirements. There was a negative correlation between land use mixedness and leisure physical activity. The accessibility of commercial facilities, catering facilities, green space facilities and sports facilities were significantly positively correlated. Compared with male, female are more affected by land use mixedness and facility accessibility. Age and marital status were not related to leisure walking activity. Monthly income showed a significant negative correlation.

Table 3-3 Multiple regression analysis results of male and female samples

	Traffic Walking Time				Leisure Walking Time			
	Male Model 5		Female Mode 6		Male Model 7		Female Mode 8	
	B	t	B	t	B	t	B	t
Population Density	-3.081	-1.491	2.700	1.575	-0.701**	-2.274	0.478*	1.858
POI Density	-48.905	-0.985	-42.215	-0.963	16.289**	2.191	1.870	0.283
Land Use Mixedness	-119.006***	-4.899	54.732**	2.395	4.046	1.159	-11.415***	-3.249
Proportion of Commercial Facilities POI	0.244**	2.011	-0.075	-0.631	-0.016	-0.879	0.054***	2.881

Proportion of Living Service Facilities POI	0.943***	2.845	-0.878***	-3.246	-0.028	-0.561	0.000	0.005
Proportion of Catering Facilities POI	1.268***	6.259	-0.146	-0.797	-0.027	-0.911	0.068**	2.411
Proportion of Park Green Space POI	5.575***	16.682	-126.488	-0.562	-0.084*	-1.672	73.321**	2.184
Proportion of Sports Facilities POI					0.061	0.582	0.371***	2.911
Main Road Density	1.227	1.385	2.120***	2.713	-0.002	-0.016	-0.009	-0.076
Branch Density	-1.093	-1.012	-1.594*	-1.846	-0.250	-1.551	-0.033	-0.252
Number of Bus Stops	-0.346	-0.405	-0.456	-0.591				
Traffic Trip Mode	-3.883**	-1.965	5.058***	2.950				
Community Safety	0.306	0.445			0.293**	1.969	0.390***	3.054
Richness of Sports Facilities					0.570	1.096	0.381	0.878
Community Life Satisfaction					0.278*	1.676	0.142	0.996
Age	-0.078	-0.341	-0.039	-0.201	-0.088**	-2.564	-0.042	-1.439
Marital Status	-1.355	-0.315	4.199	1.092	2.319***	3.611	0.368	0.640
Education	-2.561	-0.723	-8.912***	1.092	-2.561***	-4.876	-1.752***	-3.932
Monthly Income	2.884	0.895	0.599**	2.527	0.831*	1.709	-0.104***	-2.853
Love Sports					0.971***	2.621	1.537***	4.962
B	17.423	1.851	-12.985	-1.586	3.166	1.027	**2.333**	0.961
F	19.791		3.094		3.684		6.294	
Adjusted R^2	0.278		0.062		0.058		0.159	
Sig	0.000		0.000		0.000		0.000	

Notes: ***, **, * were significant at 0.01, 0.05 and 0.1 levels, respectively.

3. 4 Conclusion and discussion

This chapter researched the impact of the built environment on walking activity. The empirical results showed that the factors such as density of built environment, mixing degree of function, design, accessibility of facility, and connectivity of road traffic were related to walking activity, which is basically consistent with the research of western developed countries, but the influence mechanism of built environment factors was different. This is because the characteristics of urban development in China are different from those in the West. The conclusions are as follows:

(1) Generally speaking, the built environment had different effects on traffic walking and leisure walking. It was certain that the improvement of the built environment will help to promote the physical activity of the residents. Cao And Fan (2012) believed that after controlling the individual characteristics of residents, the

built environment still had an influence on residents' behavior and results.

(2) Traffic walking activity were affected by land use mixedness, facility accessibility and road connectivity. The urban land use mixedness was conducive to promoting the time of traffic walking activity. The convenient accessibility of commercial facilities, life service facilities, catering facilities and green space facilities promoted residents to increase traffic walking activity. The main road density promoted traffic walking, while the branch road density restrains traffic walking. Further research is needed on the influence of road connectivity.

(3) Leisure walking activity were affected by POI density, accessibility of sports facilities, branch density, community safety, richness of sports facilities and satisfaction of community life. The moderate increase of POI density and sports facilities was conducive to leisure walking activity. The density of branch road network was negatively correlated with leisure walking behavior. This was related to the residents' habit of choosing walking places and the residential area form in China. Community safety and community life satisfaction had positive effects on physical activity.

(4) From the perspective of control variables, traffic walking behavior was not affected by other individual characteristics except monthly income. For leisure walking, it was affected by the age of individual characteristics, marital status, higher education, monthly income, love of sports and other factors to varying degrees.

(5) There were great differences between male and female in the influence of built environment factors on walking activity. Compared with traffic walking activity, male and female have opposite effects on land use mixedness, facility accessibility and travel mode. There were significant differences in the influence of road density, education and monthly income. Compared with leisure walking activity, there were opposite effects on population density, accessibility of green space facilities and monthly income. There were significant differences in POI density, land use mixedness, facility accessibility, life satisfaction, age and marriage.

To sum up, in the field of urban planning, urban built environment will be conducive to promoting physical activity. The city function should be mixed moderately. The density of public service facilities should be increased appropriately. Urban public transport should be more convenient. The establishment of more fair use of sports and activity facilities, and the creation of a good community atmosphere will promote physical activity of residents, which is conducive to the enhancement of population health.

3.5 Chapter Summary

This chapter took walking as the research object, and used the method of multiple regression equation to research the impact of built environment factors on traffic walking and leisure walking. The conclusion showed that the individual characteristics had no effect on the traffic walking activity. However, the land use mixedness, main road density, branch density, commercial facilities, living facilities, catering facilities and green space facilities all had an influence on traffic walking. Leisure walking activity were affected by age, marriage, education, monthly income, love of sports. POI density, sports facilities, green space facilities, sports facilities, community safety and community life satisfaction all had an influence on leisure physical activity. The impact of built environment on leisure walking was less than that of traffic walking. From the two factors, leisure walking activity were influenced not only by the built environment, but also by other factors. These effects may be the indirect effects of the built environment on physical activity. When we study the direct influence of built environment on physical activity, we also need to study how built environment indirectly affects physical activity, and then affects health. In the separate study of male and female samples, we found that there were great differences between male and female. When carrying out the transformation of the built environment, we should fully consider the different needs of male and female for a reasonable design.

Physical activity includes walking, cycling, running and other different types. This chapter only took walking behavior as the intermediary element of health and physical activity, which had certain one sidedness. At the same time, there was a certain intersection between traffic walking time and leisure walking time, which was difficult to distinguish clearly. In the fourth chapter, we will further study the influence of high intensity physical activity as an intermediary factor.

Chapter4 - The influence path of objective characteristics and subjective perception of built environment on moderate to vigorous physical activity

4. 1 Introduction

The level of physical activity is usually described by duration, frequency, intensity, type or pattern (Katzmarzyk et al., 2007). Physical activity is measured differently in different research areas. For example, researchers in the field of urban and rural planning and transportation mainly focused on the modes of transportation such as walking, while those in the field of public health mainly focused on the total amount of leisure walking (Owen, et al. 2004) and the moderate physical activity (Frank et al., 2005). People were engaged in different types of physical activity in different environments for different purposes; on the contrary, different built environments will promote different types of physical activity (Brownson et al., 2009). Moderate to vigorous physical activity was more beneficial to human health than low intensity physical activity(Colley et al., 2013). In 2011, the World Health Organization issued guidelines on physical activity for all ages, which reaffirmed the importance of moderate physical activity in promoting health (WHO, 2011). “5 days / week, 30 minutes / day moderate intensity physical activity” is the basis of health promotion, which can effectively reduce the subcutaneous and abdominal fat, total fat percentage of adults (Irwin et al., 2003). In the previous chapter, we researched the impact of built environment on walking activity. In this chapter, we chose moderate to vigorous physical activity as the intermediary elements of built environment for health. Because the objective element of the built environment is to guide its external behavior through human perception. In the study of built environment, we included the subjective perception elements of built environment, explored the impact of environmental subjective perception on physical activity and the influence path of the objective characteristics and subjective perception on physical activity.

Cross border studies in 14 cities around the world showed that residential density, park density and bus station density can promote the moderate to vigorous physical activity of residents (Sallis et al., 2016). The empirical study in Baltimore and Atlanta showed that the residents of the community with higher walkability had the longer time of the moderate to vigorous physical activity (Carlson et al., 2012; Frank et al., 2005). The Boston survey found that the high residential density, compact urban

texture and mixed land use will make the residents develop moderate to vigorous physical activity in the community for a long time, but the above factors had no significant relationship with the daily average amount of moderate to vigorous physical activity (Troped et al., 2010). In Australia, increasing green space rate can effectively improve the probability and frequency of participation in walking and moderate to vigorous physical activity (Astell-Burt et al., 2014).

Karmeniemi's (2018) research showed that objective characteristics and subjective perception affected physical activity respectively. Rhodes and Peter (2010) believed that improving the environmental beauty was conductive to promoting leisure physical activity. No matter whether the objective neighborhood environment of the residence was the same or not, it may have different environmental perception due to different attitudes and values, and guide its own external behavior, which has a positive or negative influence on health.

Vojnovic (2006) research had shown that the shorter distance to the destinations, attrctive street views and community safety all contributed to physical activity. Foster and Giles-Corti. (2008) found that community safety perception had an important influence on the moderate to vigorous physical activity. Other scholars had shown that good environment, more green space and safe environment can improve physical activity time (Brown and Werner, 2007; Mota et al., 2005; Saelens et al., 2003). Sohn (2016) believed that the built environment had a significant influence on community safety perception. Therefore, we need to pay attention to the intermediary effect of community safety perceptio. In the study, 42.7% results showed that the community safety had a significant positive effect on physical activity. 10.1% results showed that the community safety had a significant negative effect on physical activity, 47.2% results showed that the community safety had no significant effect on physical activity (da Silva et al., 2016). However, there is little research to explore the influence path between objective characteristics, subjective perception and physical activity (Lo et al., 2019). Gebel et al. (2011) found that one third of the people's subjective perception of built environment was inconsistent with the objective indicators, which showed that the planning of healthy cities needs to pay attention to the linkage mechanism of the two.

Similarly, individual characteristics and socio-economic attributes can also affect individual physical activity. Intersection density can promote moderate to vigorous physical activity in female, but no effect on male (Troped et al., 2010). The community safety had little impact on male's walking, but positively correlated with female's walking (Humpel et al., 2004). Low income respondents were mainly involved in traffic physical activity, while high-income respondents were concerned

about lesure physical activities (Hoehner et al., 2005).

4. 2 Method and variables

4. 2. 1 Method

Multiple regression analysis was used to study the impact of subjective perception of built environment on moderate to vigorous physical activity. Regression analysis method has been described in the third chapter. And then, the path relationship between the potential variables is studied by structural equation modeling. Structural equation modeling is a powerful tool for the path analysis. The relevant equation of structural equation is shown in formula 4-1, 4-2, 4-3.

Structural equation: $\eta = \gamma\xi + \beta\eta + \zeta$ (**Formula 4-1**)

Measurement equation of internal derivative variable: $Y = \lambda\eta + \varepsilon$ (**Formula 4-2**)

Measurement equation of external derivative variable: $X = \lambda\xi + \delta$ (**Formula 4-3**)

In structural equation, η is vector type, γ is regression type, ξ is vector type, β is regression type. In the measurement equations of internal and external derivatives, λ is regression type, and ε and δ are variance / covariance type. ξ represents external derivative, η represents internal derivative, γ represents the effect of external derivative on internal derivative, and β represents the effect of internal derivative on internal derivative.

4. 2. 2 Variables

The choice of variables was put forward on the basis of existing theories and researches, combined with research problems. In this study, moderate to vigorous physical activity within one week in the community was chosen as the explanatory variable, which was measured by the length of time.

The selection of subjective perception variables of community environment was also based on the material dimension of built environment. They were environmental density perception, environmental quality perception, environmental facilities perception and environmental security perception. The environmental density perception was measured by three indicators: POI density, POI entropy index and the proportion of subjective perception of sports facilities. The environmental quality perception was measured by four indicators, the perception of community green coverage, the perception of beauty of environment facilities, the perception of environmental cleanliness, and the perception of illumination at night. The perception of environmental facilities was measured by two indicators: the convenience of

commercial shopping and the convenience of public transportation. Safety perception was measured by two indicators: community safety perception and traffic safety perception.

In the research, we also explored the influence path of the objective characteristics, subjective perception and physical activity, so we also chose the variables of objective characteristics of the built environment. The compactness of economic and social activity was evaluated by POI density; the accessibility of facility was reflected by the proportion of sports facilities POI; the diversity of urban functions was shown by the entropy index of POI; the accessibility of road design was reflected by the density of road network.

In the control variables, gender, age, marriage, education, social stratum, mental status, and love for sports are controlled. See Table 4-1 for statistics descriptive of variables.

Table 4-1 Statistics descriptive of variables

Latent Variable	Index Variable	Value Description	All Samples		Male Samples		Female Samples	
			Mean Value	S. D.	Mean Value	S. D.	Mean Value	S. D.
Physical Activity	MVPA	Unit: hours	3.04	8.99	3.89	10.98	1.73	4.06
Objective characteristics	Entropy Index of POI Type	EI=∑Si×ln(1/Si), 'Si' is the proportion of class 'i' POI amongst the total POI.	2.08	0.30	2.07	0.30	2.09	0.30
	POI Density	Unit: 10000 / km^2	0.05	0.04	0.05	0.05	0.06	0.05
	Proportion of Sports Facilities POI	Unit:%	1.94	2.93	1.94	3.03	1.95	2.80
	Road Network Density	Unit: km/km^2.	11.01	3.18	10.87	3.25	11.26	3.06
Environmental Density Perception	Entropy Index of Subjective POI Type	EI=∑Si×ln(1/Si)	0.96	0.19	0.94	0.20	0.99	0.16
	Subjective POI Density	Unit: per square metre.	16.16	7.87	16.05	8.25	16.34	7.24
	Proportion of Subjective Sports Facilities POI	Unit:%	1.00	0.98	0.96	0.98	1.06	0.99
Environmental Quality Perception	Environment Cleanliness	Very unclean=1 to very clean=4	2.78	0.71	2.73	0.70	2.86	0.73
	Subjective Green Coverage Ratio	Poor shading effect=1 to good shading effect=4	2.59	0.78	2.59	0.78	2.58	0.79
	Beauty Degree of Environment	Very ugly and messy=1 to very beautiful and harmonious=4	2.71	0.73	2.69	0.71	2.75	0.76
	Community Illuminance	Very dull=1 to very bright=4	2.61	0.76	2.59	0.76	2.64	0.78

Environmental Facilities Perception	Subjective Convenience of Shopping Facilities	Very dissatisfied=1 to very satisfied=10	7.60	1.96	7.56	1.98	7.66	1.94
	Subjective Convenience of Public Transportation	Ditto	7.30	2.06	7.16	2.09	7.51	2.00
Safety Perception	Public Safety	Ditto	7.14	2.10	7.17	2.07	7.09	2.17
	Traffic Safety	Ditto	6.82	2.18	6.80	2.17	6.85	2.21
Control Variable	Gender	Male=0, Female=1	0.39	0.49	-	-	-	-
	Age	Unit: year	31.32	9.04	31.82	9.05	30.54	8.98
	Marital Status	Unmarried=0，married=1	0.65	0.48	0.63	0.48	0.68	0.47
	Education	No higher education=0，Higher education=1	0.46	0.50	0.39	0.49	0.58	0.49
	Mental State	Always depressed=1 to never depressed=5	3.40	0.82	3.40	0.81	3.40	0.83
	Social Stratum	Bottom layer=1 to uppermost layer=5	2.45	0.90	2.45	0.92	2.46	0.88
	Love for Sports	Very loathsome=1 to very fond =4	2.79	0.74	2.93	0.70	2.57	0.74

4.2.3 Construct structural model

The factors that affect physical activity are complex. The subjective perception of the built environment not only had an effect on the moderate to vigorous physical activity, but also may be related to the objective characteristics of the built environment. In addition, the existence of individual control variables, so the study through the establishment of structural equation model, to rasearch the influence path of each potential variables. Objective characteristics of built environment, environment density perception, environment quality perception, environment facilities perception and environment safety perception were introduced into the study. The interaction path was studied by structural equation model, and the effect of each variable was analyzed by path graph and effect value. Figure 4-1 is the analysis framework of the study.

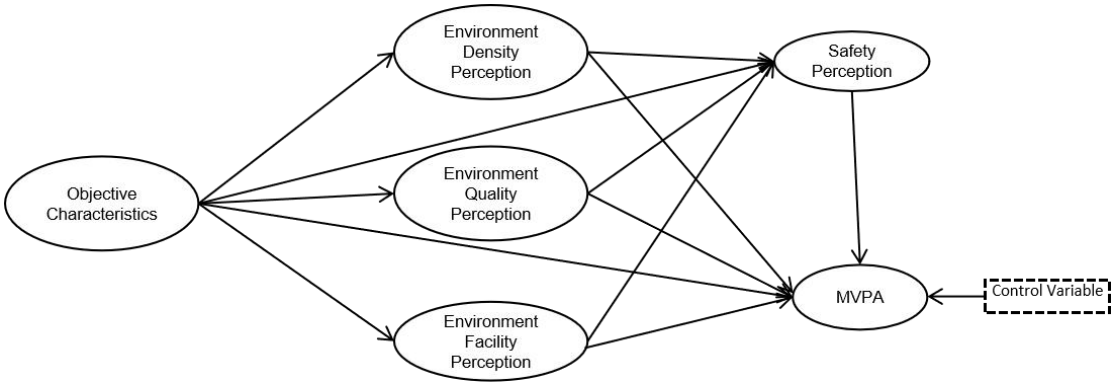

Figure 4-1 Structural equation model analysis framework

4.3 Results

4.3.1 Results of multiple regression analysis

In order to reveal the impact of subjective perception on moderate to vigorous physical activity of residents, three models were established to conduct multiple regression analysis on the samples. In model 1, the effects of environment density perception and environment quality perception on moderate to vigorous physical activity were investigated under the control of individual characteristics such as gender, age, marital status, education and social level. In model 2, mental state control was added at the individual level, and perception factors of built environmental facilities were added at the same time. Model 3 increased the control elements of self selection mechanism of sports loving degree, and the safety perception, and investigated the influence of overall environmental perception on moderate to vigorous physical activity. The three models passed the significance test of 0.001, and the specific regression results are shown in Table 4-2.

In Model 1, there was a significant positive correlation between subjective perception POI density and environment beauty perception on moderate to vigorous physical activity ($P < 0.01$). The higher the POI density of subjective perception was, the better for residents to carry out moderate to vigorous physical activity. Comfortable and beautiful environment gave people beautiful enjoyment, which was conducive to promoting the residents to have leisure physical activity. The entropy index of subjective POI and the proportion of subjective perception of sports facilities POI were correlated with moderate to vigorous physical activity ($P < 0.1$). The former showed negative correlation, while the latter showed positive correlation. In the characteristics of individual level, gender and education had a significant negative influence on the physical activity of residents ($P < 0.01$). Compared with female, male had longer times of moderate to vigorous physical activity. The social class had a significant negative effect ($P < 0.05$). This was similar to the impact of individual characteristics of education. There was a positive correlation between marital status and moderate to vigorous physical activity. Married or cohabiting residents were more willing to carry out moderate to vigorous physical activity. Age had no effect.

Regression analysis results of Model 2 showed that the influence of some variables changed. The effect of subjective POI entropy index increased by one level ($P < 0.05$). The subjective perception of sports facilities was enhanced in two levels ($P < 0.01$). There was a significant correlation between the convenience of commercial facilities and moderate to vigorous physical activity ($P < 0.05$). Subjective perception of facilities convenience will help residents to carry out leisure

physical activity. Public transport convenience had no significant effect. The influence degree of education in individual characteristics decreased one level ($P < 0.05$). The mental status was positively correlated ($P < 0.1$). Residents with better mental status are more willing to carry out leisure physical activity.

The regression analysis results of Model 3 showed that compared with Model 2, the influence of subjective POI entropy index and subjective perception of sports facilities on moderate to vigorous physical activity was reduced by one level. The influence of environmental cleanliness perception changed greatly, from uncorrelated to significantly negatively correlated ($P < 0.05$). This is contrary to conventional cognition, which needs further study. The subjective perception of sports facilities reduced one level. There was a significant correlation between the perception of community security and traffic safety on moderate to vigorous physical activity ($P < 0.01$). In individual characteristics, the influence of gender was reduced by one level, and the influence of social class was increased by one level. The influence of mental state was not related. The influence of loving sports was significant ($P < 0.01$). The influence of this self selection factor was the highest among all factors.

Table 4-2 Multiple regression analysis results

	Model 1		Model 2		Model 3	
	B	**t**	**B**	**t**	**B**	**t**
Entropy Index of Subjective POI Type	0.117***	2.894	0.137***	3.649	0.145***	3.925
Subjective POI Density	-3.154*	-1.900	-3.422**	-2.102	-2.731*	-1.717
Proportion of Subjective Sports Facilities POI	0.604*	1.744	10.455***	2.889	7.762**	2.186
Subjective Green Coverage Ratio	-0.321	-0.811	-0.373	-0.946	-0.563	-1.459
Beauty Degree of Environment	1.599***	3.580	1.317***	2.919	1.382***	3.137
Environment Cleanliness	-0.508	-1.139	-0.606	-1.354	-0.911**	-2.000
Community Illuminance	0.054	0.138	0.008	0.020	-0.085	-0.220
Subjective Convenience of Shopping Facilities			0.392**	2.282	0.350**	2.016
Subjective Convenience of Public Transportation			-0.022	-0.137	-0.060	-0.355
Public Safety					-0.687***	-4.234
Traffic Safety					0.650***	4.030
Gender	-1.932***	-3.722	-1.916***	-3.704	-1.065**	-2.028
Age	-0.021	-0.646	-0.036	-1.085	-0.007	-0.214
Marital Status	1.055*	1.705	1.117*	1.810	1.028*	1.698
Education	-1.385***	-2.739	-1.243**	-2.467	-1.201**	-2.718
Social Stratum	-0.577**	-2.025	-0.706**	-2.468	-1.046***	-3.471

Mental State			0.514*	1.663	0.203	0.665
Love for Sports					2.427***	6.822
B	2.911	1.610	-1.483	-0.494	-4.598	-1.543
F	6.336		5.782		8.742	
Adjusted R^2	0.043		0.055		0.101	
Sig	0.000		0.000		0.000	

Notes: ***, **, * were significant at 0.01, 0.05 and 0.1 levels, respectively.

4. 3. 2 Structural equation analysis results

According to the above analysis results, the initial structural equation of residents' physical activity behavior research was constructed on the Amos software platform. Four models were established to study the direct influence path of the objective characteristics and subjective perception of the built environment on the moderate to vigorous physical activity; the influence path of the community safety intermediary variables; the influence path of the objective characteristics and subjective perception of the built environment on the moderate to vigorous physical activity of male and female. The initial operation result is shown in the figure. The statistical test of CR (critical ratio) value with probability P was used to test the significance of model path coefficient. The significance of standardized path coefficient estimation is shown in the table.

4. 3. 2. 1 The impact of objective characteristics and subjective perception of built environment on moderate to vigorous physical activity

Model 1 directly studied the relationship among the objective characteristics of built environment, environment density perception, environment facilities perception, environment quality perception and moderate to vigorous physical activity. The chi square degree of freedom (Cmin / DF) of the model was 9.125. The RMSEA value of the model was 0.057. According to these indexes, we believed the structural equation model was acceptable.

The results of Model 1 (as shown in Figure 4-2) showed that the direct influence of the objective characteristics on moderate to vigorous physical activity was not significant. However, the objective characteristics had different effects on the three latent variables of subjective perception. Environmental density perception and environmental facility perception were significantly affected ($P < 0.01$), and environmental quality perception was positively affected ($P < 0.1$).Therefore, the objective characteristics of the built environment had a comprehensive impact on subjective perception. At the same time, environment density perception and environment facilities perception had significant positive effects on moderate to

vigorous physical activity. However, the effect of environment quality perception on moderate to vigorous physical activity was not statistically significant. From this point of view, the objective characteristics of built environment was to map physical activity through the transmission of subjective perception.

Gender, social level and education of the control variables had significant negative effects on the moderate to vigorous physical activity ($P < 0.01$). Stable marriage status was to promote physical activity ($P < 0.1$). The residents' love of sports was a significant positive correlation ($P < 0.01$). The influence of mental state was not obvious. This is basically consistent with the analysis results of multiple regression model.

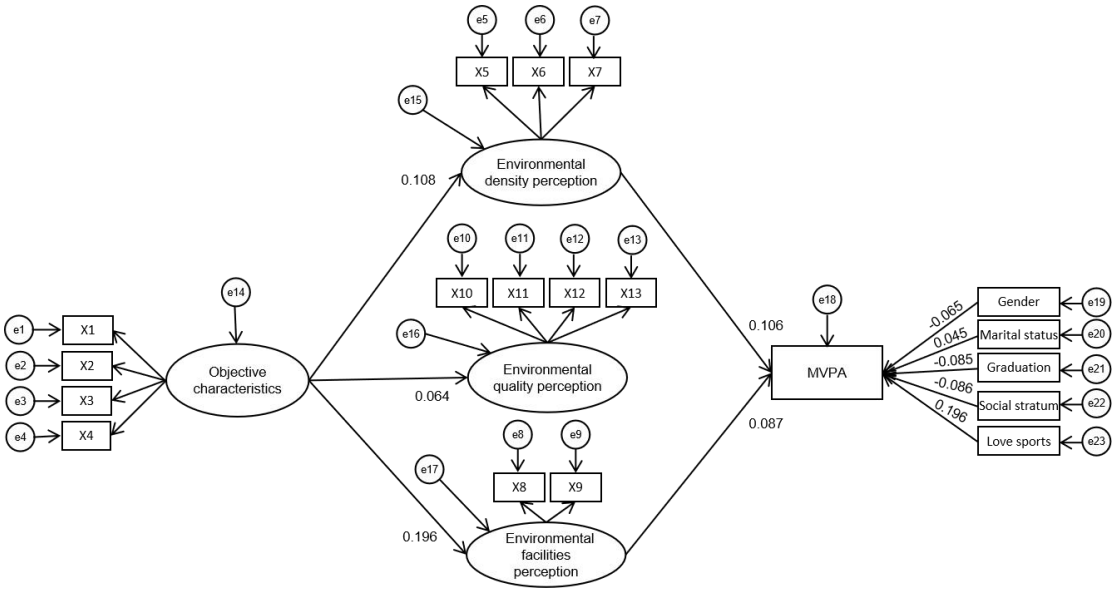

Figure 4-2 Standardized path of structural equation model 1

4.3.2.2 The impact of community safety

According to research literature, safety perception can affect physical activity, so we introduced the variable to research its role in the path of influence. Latent variables of security perception were added to Model 2. The chi square degree of freedom (Cmin / DF) of Model 2 was 8.62 and RMSEA value was 0.055, which was acceptable. Figure 4-3 shows the results of Model 2.

The results of Model 2 showed that the path results of Model 1 remained unchanged after safety perception was introduced. The objective characteristics of built environment had no direct influence on safety perception. Subjective perception had different effects on safety perception. Environment density perception had a negative correlation with community safety ($P < 0.1$), while environmental facilities

perception and environmental quality perception were more closely related to safety perception ($P < 0.01$). Community safety had a significant effect on the level of 0.01 in moderate to vigorous physical activity. It can be seen that the density of the environment was too high, which will bring insecurity to the residents, and will be unfavorable for the residents to carry out leisure physical activity. Good perception of environmental facilities and improvement of environmental quality will contribute to the improvement of residents' sense of security, and promote residents to carry out leisure physical activity. Environmental density perception and environmental facilities perception can directly and indirectly affect physical activity. Security perception was an intermediary variable. Environmental quality perception can only indirectly affect physical activity through the intermadiary role of safety perception.

From the standardized coefficient of the model, environmental facilities perception had the greatest influence on community safety perception, followed by environmental quality perception. The effect of community safety on physical activity was also higher than that of moderate to vigorous physical activity. Compared with the data in Model 1, the effect of the objective characteristics on the environmental quality perception was doubled, and the effect of the environmental facilities perception on the moderate to vigorous physical activity was doubled. Other data had not changed much. (see Table 4-4 for details)

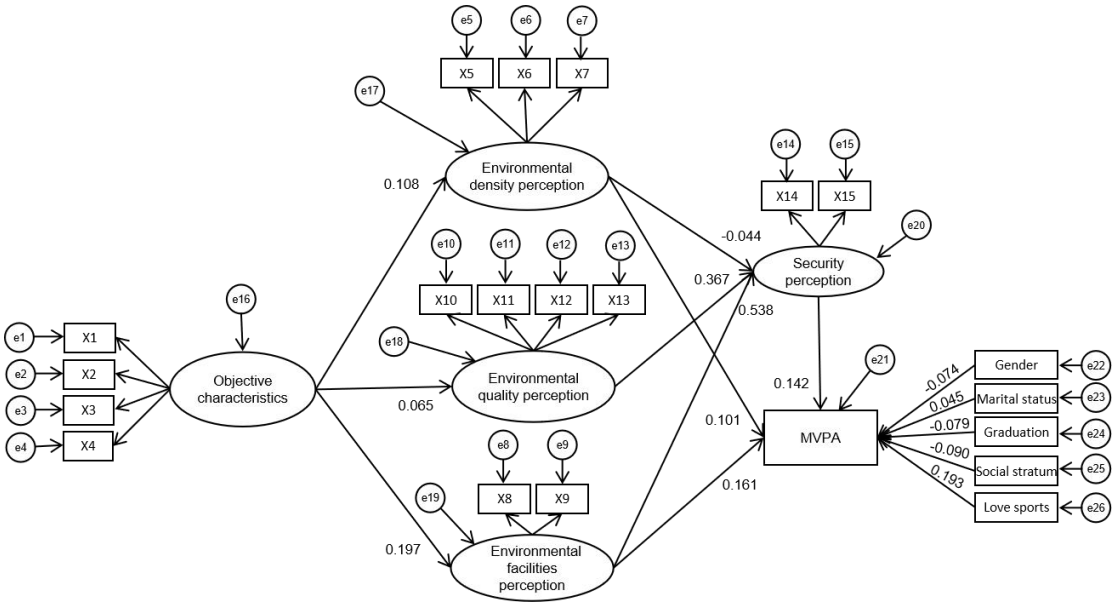

Figure 4-3 Standardized path of structural equation model 2

Table 4-4 Analysis Results of Structural Equation

Structural Equation			Model 1			Model 2		
			Estimate	S.E.	Standardized Estimate	Estimate	S.E.	Standardized Estimate
Environmental Density Perception	**<---**	**Objective Characteristics**	0.159***	0.051	0.108	0.160***	0.051	0.108
Environmental Quality Perception	**<---**	**Objective Characteristics**	0.363*	0.191	0.064	0.378*	0.195	0.197
Environmental Facilities Perception	**<---**	**Objective Characteristics**	3.609***	0.723	0.196	3.523***	0.678	0.065
Entropy Index of POI Type	**<---**	**Objective Characteristics**	1.000		0.297	1.000		0.297
POI Density	**<---**	**Objective Characteristics**	0.494***	0.050	0.902	0.494***	0.050	0.902
Proportion of Sports Facilities POI	**<---**	**Objective Characteristics**	63.294***	6.249	0.829	63.277***	6.246	0.824
Road Network Density	**<---**	**Objective Characteristics**	12.884***	1.578	0.361	12.883***	1.578	0.361
Entropy Index of Subjective POI Type	**<---**	**Environmental Density Perception**	1.000		0.693	1.000		0.693
Subjective POI Density	**<---**	**Environmental Density Perception**	44.398***	2.037	0.743	44.495***	2.040	0.744
Proportion of Subjective Sports Facilities POI	**<---**	**Environmental Density Perception**	6.198***	0.285	0.829	6.185***	0.284	0.827
Subjective Convenience of Shopping Facilities	**<---**	**Environmental Facilities Perception**	1.000		0.794	1.000		0.819
Subjective Convenience of Public Transportation	**<---**	**Environmental Facilities Perception**	0.995***	0.137	0.837	1.060***	0.050	0.811
Environment Cleanliness	**<---**	**Environmental Quality Perception**	1.000		0.722	1.000		0.736
Subjective Green Coverage Ratio	**<---**	**Environmental Quality Perception**	1.074***	0.051	0.698	1.043***	0.048	0.691
Beauty Degree of Sketch	**<---**	**Environmental Quality Perception**	1.084***	0.049	0.759	1.047***	0.046	0.748
Community Illuminance	**<---**	**Environmental Quality Perception**	0.986***	0.049	0.658	0.971***	0.047	0.662
MVPA	**<---**	**Objective Characteristics**	-4.247	3.000	-0.042	-4.517	3.000	-0.045
MVPA	**<---**	**Environmental Density**	7.224***	2.039	0.106	6.880***	2.034	0.161

		Perception						
MVPA	**<---**	**Environmental Facilities Perception**	0.475***	0.171	0.087	0.909***	0.222	0.045
MVPA	**<---**	**Environmental Quality Perception**	-0.274	0.523	-0.016	0.625	0.587	0.036
MVPA	**<---**	**Gender**	-1.189**	0.488	-0.065	-1.360***	0.486	-0.074
MVPA	**<---**	**Marital Status**	0.840*	0.499	0.045	0.838*	0.497	0.045
MVPA	**<---**	**Social stratum**	-0.856***	0.264	-0.086	-0.892***	0.263	-0.090
MVPA	**<---**	**Education**	-1.525***	0.478	-0.085	-1.423***	0.476	-0.079
MVPA	**<---**	**Mendal State**	0.279	0.292	0.025	0.335	0.290	0.031
MVPA	**<---**	**Love for Sports**	2.389***	0.324	0.196	2.346***	0.322	-0.088
Community Safety Perception	**<---**	**Safety Perception**				1.000		0.767
Traffic Safety Perception	**<---**	**Safety Perception**				0.426***	0.478	0.810
Safety Perception	**<---**	**Objective Characteristics**				-0.521	0.575	-0.023
Safety Perception	**<---**	**Environmental Density Perception**				-0.667*	0.385	-0.044
Safety Perception	**<---**	**Environmental Quality Perception**				1.424***	0.105	0.367
Safety Perception	**<---**	**Environmental Facilities Perception**				0.681***	0.038	0.538
MVPA	**<---**	**Security Perception**				0.634***	0.170	0.142
			CMIN=1479.376, df=164,CMIN/DF=9.021	RMSEA=0.057,NFI=0.772, TLI=0.732,CFI=0.791		CMIN=1543.033, df=179, CMIN/DF=8.620	RMSEA=0.055,NFI=0.787, TLI=0.749,CFI=0.805	

Notes: ***, **, * were significant at 0.01, 0.05 and 0.1 levels, respectively.

4.3.2.3 The impact of objective characteristics and subjective perception of built environment on male's moderate to vigorous physical activity

Model 3 used male sample data for structural equation regression analysis, and Figure 4-4 shows the results. There were six main paths. For male, the objective characteristics of the built environment had less influence on subjective perception, only in the environmental facilities perception. The potential variables of objective characteristics had a direct influence on the moderate to vigorous physical activity and community safety. Environmental density perception can't affect physical activity through safety perception. These characteristics were very different from the whole sample. Only the social stratum and the sports loving degree affected the moderate to vigorous physical activity. The results were consistent with the third chapter. Table 4-5 is the specific fitting index of structural equation model.

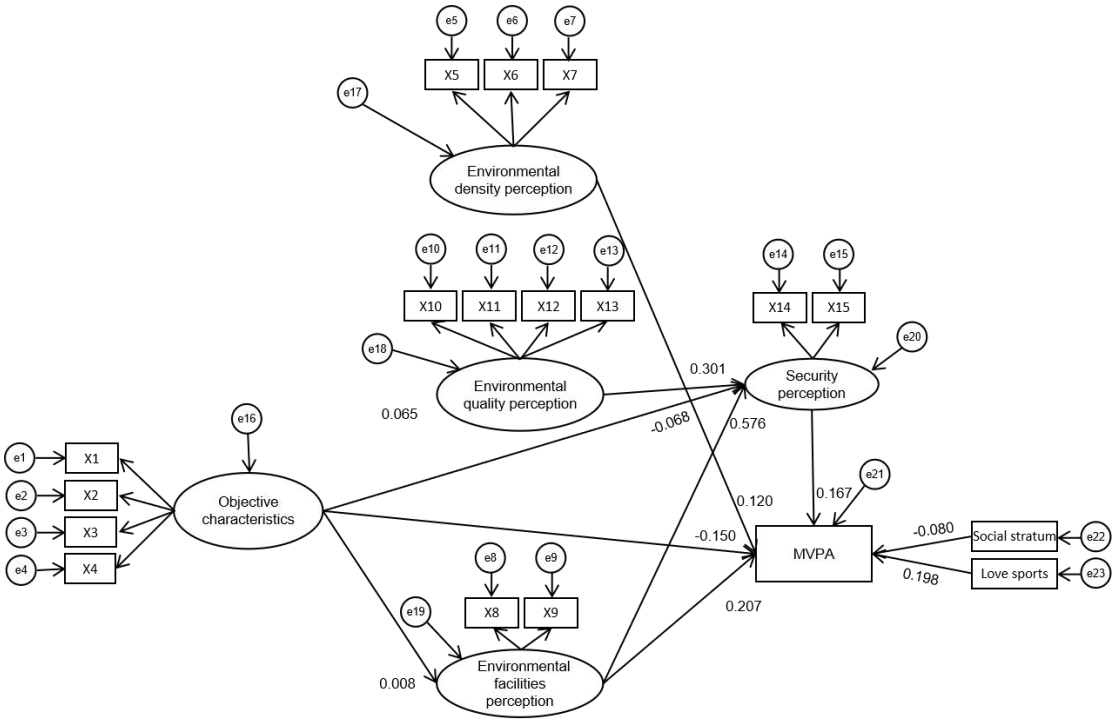

Figure 4-4 Standardized path of male data structure equation model 3

4.3.2.4 The impact of objective characteristics and subjective perception of built environment on female's moderate to vigorous physical activity

Model 4 used female sample data for structural equation model analysis. Figure 4-5 shows the model analysis results. We can see that the path of influence was quite different from that of male. Subjective perception of residents affected by objective characteristics. But they did not directly affect the moderate to vigorous physical activity of female. There were two main influence paths for the built environment on female. From these two paths, the influence of built environment on physical activity was indirect. Subjective perception and security perception were very important connecting elements. Female was greatly affected by their personal characteristics, including age, marital status, mental status, social stratum and love of sports. This was also consistent with the results of the third part of multiple regression analysis.

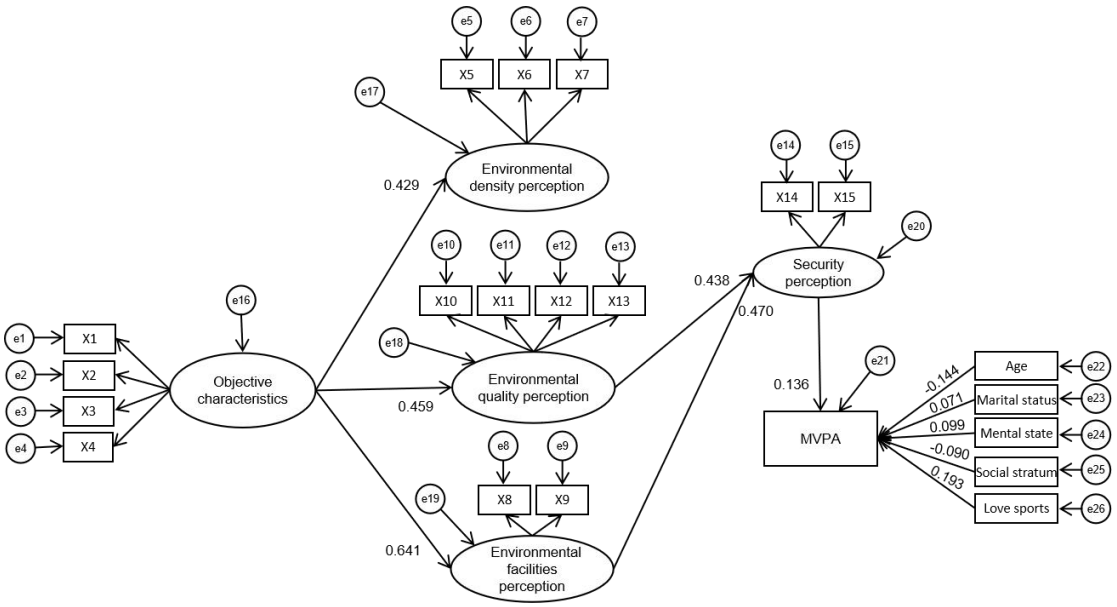

Figure 4-5 Standardization path of structural equation model 3 of female data

Table 4-5 Analysis results of structural equation of male and female samples

Structural Equation			Male Model 3			Female Model 4		
			Estimate	S. E.	Standardized Estimate	Estimate	S.E.	Standardized Estimate
Environmental Density Perception	**<---**	**Objective Characteristics**	0.060	0.049	0.060	0.361***	0.066	0.429
Environmental Quality Perception	**<---**	**Objective Characteristics**	0.028	0.177	0.008	1.748***	0.307	0.459
Environmental Facilities Perception	**<---**	**Objective Characteristics**	0.924*	0.549	0.085	7.583***	1.136	0.641
Entropy Index of POI Type	**<---**	**Objective Characteristics**	1.000	--	0.463	1.000	--	0.472
POI Density	**<---**	**Objective Characteristics**	0.171***	0.021	0.485	0.185***	0.028	0.537
Proportion of Sports Facilities POI	**<---**	**Objective Characteristics**	0.789	0.957	0.037	-2.618**	1.134	-0.131
Road Network Density	**<---**	**Objective Characteristics**	17.166***	2.506	0.740	6.750***	1.395	0.020
Entropy Index of Subjective POI Type	**<---**	**Environmental Density Perception**	1.000	--	0.690	1.000	--	0.720
Subjective POI Density	**<---**	**Environmental Density Perception**	45.386***	2.670	0.765	44.853***	3.170	0.731

Perception of Subjective Sports Facilities POI	**<---**	**Environmental Density Perception**	5.693***	0.336	0.810	6.975***	0.481	0.830
Subjective Convenience of Shopping Facilities	**<---**	**Environmental Facilities Perception**	1.000	--	0.773	1.000	--	0.858
Subjective Convenience of Public Transportation	**<---**	**Environmental Facilities Perception**	1.150***	0.069	0.843	0.962***	0.063	0.801
Environment Cleanliness	**<---**	**Environmental Quality Perception**	1.000	--	0.719	1.000	--	0.760
Subjective Green Coverage Ratio	**<---**	**Environmental Quality Perception**	1.040***	0.064	0.671	1.057***	0.073	0.719
Beauty Degree of Sketch	**<---**	**Environmental Quality Perception**	1.106***	0.061	0.791	0.990***	0.070	0.698
Community Illuminance	**<---**	**Environmental Quality Perception**	1.009***	0.062	0.665	0.927***	0.069	0.654
MVPA	**<---**	**Objective Characteristics**	-11.697***	3.523	-0.150	4.896	3.666	0.167
MVPA	**<---**	**Environmental Density Perception**	9.439***	3.012	0.120	0.707	2.0333	0.020
MVPA	**<---**	**Environmental Facilities Perception**	1.481***	0.369	0.207	0.049	0.226	0.020
MVPA	**<---**	**Environmental Quality Perception**	0.827	0.901	0.038	-0.594	0.543	-0.077
MVPA	**<---**	**Age**	0.029	0.041	0.024	-0.066***	0.019	-0.144
MVPA	**<---**	**Marital Status**	0.195	0.456	0.042	0.621*	0.368	0.071
MVPA	**<---**	**Social stratum**	-0.956**	0.404	-0.080	-0.424**	0.196	-0.090
MVPA	**<---**	**Education**	-2.113***	0.756	-0.097	-0.262	0.126	-0.053
MVPA	**<---**	**Mental State**	0.195	0.456	0.014	0.492**	0.208	0.099
MVPA	**<---**	**Love for Sports**	3.109***	0.531	0.198	1.002***	0.232	0.180
Community Safety Perception	**<---**	**Security Perception**	1.000	--	0.402	1.000	--	0.782
Traffic Safety Perception	**<---**	**Security Perception**	0.125***	0.026	0.119	0.205***	0.024	0.439
Security Perception	**<---**	**Objective Characteristics**	-0.956*	0.531	-0.068	-0.147	1.502	-0.010
Security Perception	**<---**	**Environmental Density Perception**	-0.722	0.460	0.051	-1.042	0.844	-0.057
Security Perception	**<---**	**Environmental Quality Perception**	1.182***	0.134	0.301	1.758***	0.208	0.438

Security Perception	**<---**	**Environmental Facilities Perception**	0.745***	0.050	0.576	0.606***	0.090	0.470
MVPA	**<---**	**Security Perception**	0.921***	0.270	0.167	0.262**	0.126	0.136
			CMIN=1181.133, df=160, CMIN/DF=7.382	RMSEA=0.088, NFI=0.706, TLI=0.649, CFI=0.732		CMIN=979.830, df=179, CMIN/DF=5.474	RMSEA=0.091,NFI=0.673, TLI=0.626,CFI=0.710	

Notes: ***, **, * were significant at 0.01, 0.05 and 0.1 levels, respectively.

4. 4 Conclusion and discussion

In this study, by establishing multiple regression equations, the influence of built environmental perception on the moderate to vigorous physical activity of residents was demonstrated. And through structural equation model method, the influence path of objective characteristics, subjective perception and physical activity was studied. Finally, the differences between male and female were compared. The findings are as follows:

First, after controlling the characteristics of individual level, the subjective perception of built environment had an independent and significant influence on physical activity of residents.

Second, The built environment indirectly affected physical activity. Subjective perception of environment was the key intermediary element. The built environment must pass the subjective perception to transmit the influence to the residents' activities. The intermediary effect of safety perception was very obvious. The space shaping of the built environment should be conducive to the communication of residents. The space where residents were willing to have social interaction was often a space with high sense of safety. We should pay attention to residents' subjective perception, build a community with pleasant space, appropriate function, convenience and safety, which will help residents carry out leisure physical activity.

Third, male were more willing to take part in moderate to vigorous physical activities than female. Residents of high social class and higher education had less time to participate in moderate to vigorous physical activities. Marriage status and love for sports had positive effects. The influence of mental state on physical activity had appeared in multiple regression analysis, but it was not significant in structural equation. The influence of mental state will be further studied in the future.

Fourth, the influence path of male and female was quite different. The built environment can directly affect male's physical activity, and it can also affect physical activity through the intermediary role of environment facilities perception and

community safety. The built environment had no direct influence on female. It needed to affect community safety through environment quality perception and environment facilities perception, and then affected physical activity. In the aspect of individual characteristics, male were only influenced by social stratum and sports loving degree, while female was influenced by age, marriage, education, mental state, social stratum and sports loving degree.

4.5 Chapter Summary

In this chapter, we used the method of multiple regression to build three models to explore the influence of different types of environmental subjective perception on moderate to vigorous physical activity. This showed that the subjective perception is the object we need to pay special attention to when we study the influence of built environment on physical activity. Then, using the method of structural equation model, this chapter researched the influence path of built environment on physical activity. Finally, the differences of the influence paths of male and female were compared. The conclusion showed that subjective perception and safety perception played an important role in the influence of built environment on physical activity. Security perception also worked through subjective perception. Generally speaking, the better the construction and maintenance of all kinds of environment in the community, residents had a good subjective perception, and they were more active in physical activities. The built environment had a direct influence on male's physical activity, and there was a certain intermediary influence on environmental facilities perception and community safety. On the other hand, for female, the built environment had an influence on physical activity through the intermediary role of environmental perception and safety perception.

The research in this chapter can see that the impact of the built environment on physical activity was not direct, but more through subjective perception and safety perception. This can be used for reference in the establishment of active spatial intervention to promote the health of Chinese residents. While paying attention to the construction of urban space, we should pay attention to community governance and build a safe community.

The third and fourth chapter mainly study the impact of built environment on health through the intermediary elements of physical activity. In the next chapter, we will study the impact of the built environment on the self-rated health of residents. At the same time, on the basis of the built environment, we will add elements of social environment to study the influence on health of residents. This is a further in-depth

study of community environmental factors related to health of residents.

Chapter 5 - The impact of built environment on residents' self-rated health

5.1 Introduction

Rapid urbanization has greatly changed the living environment of human beings, and also brought about the improvement of life expectancy and living standards of residents (Bassani, 2007; Hanibuchi et al., 2010). Previous studies had shown that with the improvement of living standards, people paid more attention to physical and mental health and were willing to spend more money on medical treatment (Breyer and Felder, 2006; Lubitz et al., 2003). This was especially true in China. People pay more attention to physical activity and health preservation for health. However, there was no detailed study on how the government should intervene in the construction of environment more accurately to improve the health of residents..

Generally, the measurement of health can be divided into objective evaluation and subjective evaluation. Objective evaluation of health is generally used by doctors to evaluate people's health. Self-rated health refers to the subjective evaluation of one's own health status, which is based on one's subjective judgment. This concept was first proposed by Suchman et al. In 1958. Since then, many scholars had enriched and improved this concept. Self-rated health had become one of the more common health measurement methods in the world. The research fields of self-rated health as health indicators include psychology, sociology, gerontology, medicine, public health and other fields (Lv, 2018).

The first two chapters studied and determined the impact of the built environment on walking behavior and moderate to vigorous physical activity. The built environment is also considered to be a key factor affecting health. After 2000, a large number of studies on this content emerged in the West (Ellen et al., 2001; Patel et al., 2003; Hill et al., 2005; Subramanian et al., 2006; Wen et al., 2006; Roh et al., 2011). Previous studies had shown that compact built environment, i.e. high density, high mixing, high connectivity, proximity to destinations and bus stops, can effectively reduce the risk of overweight and obesity (Bodea et al., 2009), improve self-rated health (Ermagun and Levinson, 2017; Liu et al., 2017), and to some extent, reveal the quality of life (Bird and Fremont, 1991).

The connotation of social environment was rich. A large number of studies had shown that those with broader and stronger social relationships and social support reported better health and lower risk of mortality (Mullins, et al., 1996; Leviton et al.,

2000; Freudenberg, 2000). Social environment can directly or indirectly affect residents' thinking and behavior, thus affecting their health behavior and health status (Sampson et al. 2002). The social environment associated with health includes social capital (Mohnen et al., 2011; Wen et al. 2003), sense of belonging (Shields, 2008), safety perception / crime (Berglund et al. 2017), residential stability, community culture (Wen et al. 2003). Pickett and Pearl et al. (2001) believed that social environment had a certain influence on health. Lee et al. (2015) thought that trust, communication and mutual help of neighbors were conducive to the improvement of self-rated health value through empirical research of Korean data. Studies showed that the social environment in Japan was related to the improvement of physical health (Murayama et al., 2013; Fujisawa et al., 2009; Ichida et al., 2009). A good community social environment affected the physical and mental health of the residents by strengthening the community management norms, creating a safe and stable environment, promoting neighborhood exchanges, promoting physical activity, reducing mental pressure.

Kim (2016) conducted an empirical study on Columbus City in the United States, established a comprehensive data set of environmental perception, built environmental objective characteristics and self-rated health, and found that walking friendly neighborhood perception characteristics were significantly positively correlated with self-rated health, on the contrary, built environment objective characteristics had little influence on self-rated health. As far as the road network structure was concerned, the larger the area of a single block was, the higher the obesity rate in the community will be; the higher the density of road intersections, the lower the obesity rate will be (Samimi et al. 2009). And it will have a significant positive influence on the self-evaluation and doctor evaluation of the overall health status (Kelly-Schwartz et al., 2004), which reflected the important value of small blocks in the construction of healthy city. Leslie and Cerin (2008) conducted an empirical study in Australia and found that many factors of neighborhood satisfaction (such as safety, walkability, social network, traffic noise) and mental health were related, but the objective environment factors had no significant influence on health. There was some evidence that there was a positive relevance between built environment and health in China (Zimmer et al., 2007), Japan (Takano, 2002) and South Korea (Lee et al., 2015). Liu et al. (2018) showed that in China, Japan and South Korea, the built environment and social environment were independently and positively correlated with residents' self-rated health. However, when it was included in a regression analysis model, the correlation was not obvious in Japan and South Korea . Empirical research in China found that environmental satisfaction, community

attachment and safety perception were closely related to self-rated health (Wen et al., 2010) .

The research on neighborhood environment and health of residents started late in China, mainly focusing on the impact of built environment such as land use, road traffic and public facilities on health of residents, but less attention was paid to social environmental factors. And the division of physical environment and social environment was often discussed, and the joint effect of the two on health was ignored (Wen and Zhang, 2009). So in this chapter, when we studied the impact of built environment on self-rated health, we also considered the impact of social environment.

5.2 Method and variables

5.2.1 Method

This research adopted the method of multiple regression equation. Based on relevant theories and methods, five models were divided to explore the influence factors and influence degree of built environment and social environment on self-rated health. The explained variable of all models was self-rated health. All models control the individual characteristics of respondents. The characteristics of built environment and social environment were set as independent variables in the model. In Model 1, the independent impact of built environment on residents' self-rated health were analyzed. In Model 2, based on the built environment, individual travel mode, moderate to vigorous physical activity and sports loving degree were increased, and analyzed whether the built environment has changed the impact after the factors of individual physical activity were increased. In Model 3, subjective perception factors of built environment were added, including walking environment satisfaction, environmental facilities perception and sports facilities richness perception. To study the impact of subjective perception, objective characteristics on self-rated health. In Model 4, social environment elements, including community safety, community life attachment perception and community management perception were added. To study the impact of built environment and social environment on self-rated health. Because the self-rated health is closely related to chronic diseases, and there was evidence that the community environment was related to the incidence of chronic diseases (Freedman et al., 2011). Patients with chronic diseases may be more dependent on the environment and have a stronger sense of the environment. Therefore, Model 5 increased the number of chronic disease categories as explanatory variables to study the impact of built environment and social

environment on self-rated health after chronic disease control. All variables were standardized and included in the regression equation.

5.2.2 Variables

Self-rated health refers to an individual's evaluation of his or her current health status. It is commonly used in medicine, psychology, sociology, public health and other fields. The residents' self-rated health is based on a scale of 1-10. 1 means poor health, 10 means very healthy, with a gradient score from poor to good. The self-rated health value of residents was 7.13, which was at a general level. At the same time, we asked the respondents in the questionnaire that “how many points are considered healthy?”. The average score was 7.55. This showed that the current self-rated health value was slightly lower than the recognition score of health.

The data of population density, POI density and land use mixing degree have been expressed in the third chapter. It will not be described here. See Table 5-1 for details. The comprehensive perception coefficient was used in the perception of environmental facilities and community attachment. The comprehensive perception of environmental facilities was measured by three indicators, namely, the perception of commercial shopping facilities, the perception of medical and health facilities, and the perception of public transport. The 10 point scoring method was used for evaluation. The comprehensive sense of community attachment was measured by eight levels of social interaction indicators. First, do you know most of the neighbors in this unit? Second, can you borrow tools from the neighbors? Third, can you find a neighbor to chat with? Fourth, can you borrow money from the neighbors when you have an urgent need? Fifth, are the neighbors trustworthy? Sixth, are the neighbors consistent with my values? Seventh, will you go to the neighborhood committee for help in case of difficulties? Eighth, are community activities diverse? These variables were measured in four levels: 1 is totally inconsistent, 4 is completely consistent.

After assigning, summing up and averaging the environmental perception indicators of residents in different dimensions, the comprehensive index of environmental perception of residents in this dimension can be obtained (see Formula 5-1). Where p_{mij} is the value assigned to the m-th perception of the i-th residents of the j-th class, n is the number of the j-th dimension or j-th type, and p_{mj} is the m-th perception index of the j-th type residents. The average comprehensive perception of environmental facilities was 7.19. The average comprehensive perception of social attachment was 2.44.

$$P_{mj} = \frac{1}{n}\sum_{i=1}^{n} P_{mij} \qquad \text{(Formula 5-1)}$$

In the control variables, gender, age, higher education or not, marital status had been descriptive statistics in Chapter 3, and mental status in Chapter 4, which were not included here. The index of the number of chronic diseases refers to the number of chronic diseases such as obesity, hypertension, diabetes, heart disease, hyperlipidemia and hyperglycemia reported by residents themselves. The judgment of social stratum was that residents report their own social stratum according to their income, 1 for the lower stratum, 3 for the middle stratum and 5 for the upper stratum. Working status referred to whether the residents participate in various types of social work, unemployment and retirement belong to those who did not participate in social work, with a value of 0. If you were working or receiving education, the value was 1. The proportion of people participating in the work was 90.52% , the rate was high.

Table 5-1 Statistics description of variables

Variables	Value Description	All Samples		Male		Female	
		Mean Value	S.D.	Mean Value	S.D.	Mean Value	S.D.
Explained Variable							
Self-Rated Health	Poor health=1 ~ Very healthy=10	7.13	1.79	7.20	1.87	7.04	1.66
Explanatory Variable							
Population Density	Unit: 10,000 people/km^2	1.55	1.24	1.45	1.19	1.72	1.30
POI Density	Unit: 10000 / km^2	0.05	0.04	0.05	0.05	0.06	0.05
Land Use Mixedness	HH=$\sum_{i=1}^{16}(S_i - x_i)^2$	0.41	0.26	0.40	0.26	0.42	0.25
Main Road Network Density	Unit:km/km^2	11.02	3.18	10.87	3.25	11.26	3.06
Branch Network Density	Ditto	7.84	2.66	7.78	2.61	7.94	2.73
Proportion of Commercial Facilities POI	Unit：%	30.00	21.50	29.95	21.90	30.09	20.89
Proportion of Living Service Facilities POI	Ditto	14.06	10.34	13.79	10.35	14.47	10.34
Proportion of Catering Facilities POI	Ditto	20.48	15.32	19.99	15.60	21.24	14.86
Proportion of Park Green Space POI	Ditto	1.56	5.31	1.57	5.61	1.57	4.81
Proportion of Sports Facilities POI	Ditto	1.94	2.93	1.94	3.03	1.95	2.80
Number of Bus Stops	Unit：Number	3.17	2.86	3.04	2.90	3.37	2.80
Traffic Trip Mode	Individual mobility=1；Public transportation=2；Individual immobilisation=3	1.62	0.87	1.62	0.88	1.61	0.85
MVPA	Unit: hour	3.04	8.98	3.89	10.98	1.73	4.06
Love Sports	Very loathsome=1=1~Very fond =4	2.79	0.74	2.93	0.70	2.57	0.74
Walking Environment Quality Perception	Very dissatisfied=1~Very satisfied=4	2.73	0.72	2.67	0.60	2.73	0.62
Environmental Facilities Perception	Very inconvenient=1~Very convenient=10	7.19	1.84	7.08	1.83	7.34	1.83

Richness of Sports Facilities	Very scarce=1 ~ Very rich=5	3.60	1.04	3.60	1.08	3.60	1.00
Community Safety	Very worried=1~ Very not worried=10	7.14	2.10	7.17	2.07	7.09	2.17
Community Attachment	Very disagree=1,; Very much=4	2.44	0.79	2.31	0.77	2.41	0.80
Community Management Satisfaction	Very dissatisfied=1,; Very satisfied=10	6.45	2.41	6.18	2.39	6.55	2.34
Number of chronic diseases	Number of chronic diseases such as obesity, hypertension, diabetes, heart disease, hyperlipidemia and hyperglycemia	0.20	0.47	0.20	0.50	0.19	0.43
Control Variable							
Gender	Male=0，Female=1	0.39	0.49	-	-	-	-
Age	Unit：year	31.32	9.04	31.82	9.05	30.54	8.98
Education	No higher education=0，Higher education=1	0.46	0.50	0.39	0.49	0.58	0.49
Marital Status	Unmarried=0，Married=1	0.65	0.48	0.63	0.48	0.68	0.47
Social Stratum	Lowest layer=1~Topmost=5	2.45	0.90	2.45	0.92	2.46	0.88
Working State	Unemploymen or retirement = 0; work or education = 1	0.91	0.29	0.92	0.26	0.88	0.33
Mental State	Always depressed=1~ Never depressed=5	3.40	0.82	3.40	0.81	3.40	0.83

5.3 Results

5.3.1 Influence of built environment on self-rated health of all samples

The results of Model 1 (Table 5-2) showed that the functional mixing degree of built environment was positively correlated with the self-rated health of residents ($P < 0.01$). The more mixed the functions, the better the self-rated health value of residents. But, the proportion of living service facilities POI and sports facilities POI was negatively correlated with self-rated health ($P < 0.01$). This meant that a certain type of facilities setting will not play a decisive role. The combination of multiple facilities was the most conducive to the health of residents. Population density, POI density, road network density, commercial facilities, catering facilities and green space facilities had no significant correlation with self-rated health of residents. The number of bus stops was correlated with self-rated health, but had a negative influence. In the control variables, age and gender showed negative correlation ($P < 0.1$). Female's self-rated health value was higher than male's. The younger the age, the higher the self-rated health value. There was a positive correlation between marital status and self-rated health ($P < 0.1$). Marriage was good for health. There was a significant positive correlation between social stratum, working state and mental state and self-rated health ($P < 0.01$). The higher the social stratum, the higher the self-rated

health value. Residents with higher social stratum paid more attention to their health, and had better economic conditions to invest more money in health care. Taking part in all kinds of social work will contribute to the health of the residents. The better the mental state, the higher the self-rated health value. The correlation between education and self-rated health was not obvious.

In Model 2, personal travel and movement state variables were added. The results of the model showed that individual travel mode had no significant influence on health of residents. There was a significant positive correlation between the degree of love for sports and the moderate to vigorous physical activity ($P < 0.01$). Compared with the residents who loved sports and active physical activity, their health status was better. There was no change in the overall influence trend of each variable of the built environment, only a slight change in the influence value. There were some changes in individual characteristic variables. The influence of gender and age were not correlated ($P > 0.1$). The influence of social stratum changed from the significant correlation ($P < 0.01$) to the correlation ($P < 0.1$). The influence of working state also had the secondary significant correlation ($P < 0.05$) change to correlation ($P < 0.1$). The reasons for the great changes in the influence of individual characteristics were the degree of love for sports and the influence of moderate to vigorous physical activity covering the influence of other individual characteristics.

In the fourth chapter, we found that subjective perception of built environment was very important to physical activity. So Model 3 included subjective perception variables of built environment. The results showed that there was a significant correlation between the perception of walking environment quality and residents' self-rated health ($P < 0.01$), but there was no correlation between the richness of sports facilities. It showed that the built environment had a good perception, which was helpful to promote the health of residents. The impact of land use mixedness changed from significant correlation ($P < 0.01$) to correlation ($P < 0.1$). Some changes had taken place at the control variables. The influence of marital status increased by one level. Age showed a correlation ($P< 0.1$). The influence of social stratum and work status changed to no.

The results of Model 4 showed that there was a significant positive correlation between community life attachment and self-rated health ($P < 0.01$). There was a secondary significant positive correlation on safety perception and community management level perception ($P < 0.05$). Community attachment represents social integration, which can improve health by increasing social support, material, cultural and psychological resources (Ross, 2002). Canadian empirical research had also found that a strong sense of community attachment was related to a higher overall

self-rated health and mental health (Hystad and Carpiano, 2012; Doyle et al., 2006). A community with a good sense of safety can promote physical activity and social interaction of residents, thus improving the health status of residents. The impact of the built environment variables and Model 3 were basically unchanged. But the subjective perception variables of the built environment had changed a lot. There was no correlation between the walking environmental quality perception and residents' self-rated health. The effect of environment facilities perception changed from significant correlation ($P < 0.01$) to correlation ($P < 0.1$). This showed that the positive influence of a good social environment on health was even stronger than the built environment. Among the control variables, work status and self-rated health of residents showed a secondary significant positive correlation again.

The results of Model 5 showed that there was a significant negative correlation between the number of chronic diseases and self-rated health ($P < 0.01$). The variables of built environmental factors had basically not changed. Compared with the results of Model 4, the perception of walking environment increased to a secondary significant positive correlation. The correlation of age, marital status and self-rated health was not significant. The influence of chronic diseases on subjective perception of built environment was more obvious. It was also worth noting that the influence of social environment was still very large when the individual characteristics were controlled, which showed that the influence of social environment on health is more direct.

Table 5-2 Multiple regression analysis results of self-rated health of residents

	Model 1		Model 2		Model 3		Model 4		Model 5	
	B	t	B	t	B	t	B	t	B	t
Population Density	0.058	1.036	-0.036	-0.674	-0，.030	-0.571	0.024	0.460		
POI Density	2.061	1.486	1.267	0.940	0.605	0.458	1.052	0.812	0.462	0.364
Land Use Mixedness	2.109***	2.910	1.905***	2.719	1.131*	1.747	1.307*	1.948	1.117*	1.702
Proportion of Commercial Facilities POI	-9.085E-5	-0.025	0.001	0.-158	0.002	0.506	0.003	0.820	0.007	1.288
Proportion of Living Service Facilities POI	-0.049***	-5.270	-0.045***	-4.906	-0.041***	-4.593	-0.038***	-4.310	-0.036***	-4.243
Proportion of Catering Facilities POI	0.004	0.709	0.005	0.851	0.006	1.108	0.007	1.335	0.008	1.403
Proportion of Park Green Space POI	-0.016	1.637	-0.014	-1.454	-0.004	-0.388	-0.007	-0.740	-0.001	-0.125

Proportion of Sports Facilities POI	-0.096***	-4.686	-0.076***	-3.818	-0.064***	-3.326	-0.067***	-3.527	-0.072***	-3.848
Main Road Network Density	-0.030	-1.202	-0.010	-0.430	-0.007	-0.283	0.004	0.175	0.001	0.058
Branch Network Density	0.030	1.049	0.014	0.509	0.006	0.230	-0.009	-0.319	-0.019	-0.718
Number of Bus Stops	-0.045*	-1.840	-0.045*	-1.905	-0.038*	-1.667	-0.040*	-1.789	-0.024	-1.106
Traffic Trip Mode			-0.044	-0.801	-0.037	-0.698	-0.025	-0.476	-0.009	-0.170
MVPA			0.018***	3.411	0.014***	2.744	0.015***	2.989	0.013***	2.610
Love Sports			0.552***	8.225	0.518***	7.923	0.462***	6.977	0.443***	6.945
Walking Environment Quality Perception					0.092***	3.538	0.058	0.668	0.065**	2.385
Environmental Facilities Perception					0.130***	4.143	0.064*	1.806	0.062*	1.757
Richness of Sports Facilities					-0.132	-1.499	-0.122	-1.400	-0.129	-1.489
Community Safety							0.069**	2.403	0.050*	1.856
Community Attachment							0.354***	5.647	0.363***	5.940
Community Management Satisfaction							0.064**	2.251	0.056**	2.039
Number of chronic diseases									-0.725***	-7.652
Gender	-0.175*	-1.774	0.066	-0.666	-0.002	-0.023	-0.052	-0.544	-0.063	-0.673
Age	-0.012*	-1.872	-0.008	1.813	-0.011*	-1.921	-0.010*	-1.743	-0.001	-0.137
Marital Status	0.224*	1.882	0.205*	1.766	0.266**	2.358	0.194*	1.743	0.166	1.521
Education	-0.056	-0.574	-0.039	-0405	-0.026	-0.275	0.011	0.114	0.064	0.708
Social Stratum	0.179***	3.379	0.093*	1.763	-0.006	-0.108	-0.044	-0.842	-0.043	-0.853
Working State	0.339**	2.011	0.292*	1.742	0.258	1.583	0.348**	2.161	0.425***	2.694
Mental State	0.625***	10.791	0.545***	9.634	0.454***	8.133	0.405***	7.301	0.346***	6.314
B	4.566***	13.731	3.255***	8.447	3.169***	5.674	2.965***	5.294	3.063***	5.657
F	12.532		15.962		17.749		17.929		20.895	
Adjusted R^2	0.137		0.194		0.235		0.259		0.291	
Sig	0.000		0.000		0.000		0.000		0.000	

Notes: ***, **, * were significant at 0.01, 0.05 and 0.1 levels, respectively.

5.3.2 Influence of built environment on self-rated health of male and female

We used data from male's surveys in Model 5.1. The results of multiple regression equation showed that part of the built environment factors had an influence on self-rated health. The proportion of living facilities POI and sports facilities POI was negatively correlated with male's self-rated health. This result was consistent with the influence direction of all samples, but the influence level was reduced to different degrees. The catering facilities showed a secondary significant positive correlation ($P< 0.05$). The convenience of catering facilities was conducive to promoting male's

self-rated health value. The main road density had a secondary significant positive correlation ($P < 0.05$). The branch density had a significant negative correlation ($P < 0.01$). These results were different from the whole sample. It showed that road density had a significant effect on male. For the subjective perception, the comprehensive perception of environmental facilities maintained a significant positive correlation. For the social environment, community security and community attachment still maintained a positive influence. For the perspective of individual characteristics, the relationship between education, social stratum and self-rated health had changed from uncorrelated to negatively correlated.

We used data from female's surveys in Model 5.2. The influence of built environment factors on self-rated health was less than that of male. The proportion of catering facilities POI and road density had no effect on female's self-rated health. In addition, the negative effect of moderate to vigorous physical activity on self-rated health was contrary to the analysis results of all samples and male samples. The influence of subjective perception was not significant. The social environment remained significant. Among the variables of personal characteristics, education, social stratum, working state and mental state were all positively correlated with female's self-rated health. The influence of education and social stratum was opposite to that of male. Female with higher education and social stratum had higher self-rated health value. Table 5-3 shows the results of multiple regression analysis.

Table 5-3 Multiple regression analysis of self-rated health of male and female

	Model 5.1（Male）		Model 5.2（Female）	
	B	**t**	**B**	**t**
Population Density	0.064	1.231	0.059	0.824
POI Density	-0.340	-0.203	0.900	0.563
Land Use Mixedness	0.383	0.468	1.624	0.491
Proportion of Commercial Facilities POI	-0.002	-0.574	0.005	0.909
Proportion of Living Service Facilities POI	-0.026**	-2.275	-0.044***	-3.446
Proportion of Catering Facilities POI	0.015**	2.265	-0.006	-0.738
Proportion of Park Green Space POI	-0.001	-0.101	0.002	0.161
Proportion of in Sports Facilities POI	-0.041*	-1.752	-0.128***	-4.406
Main Road Network Density	0.063**	2.124	-0.030	-0.947
Branch Network Density	-0.104***	-2.887	0.040	1.135
Number of Bus Stops	-0.026	-0.908	0.000	0.006
Traffic Trip Mode	0.005	0.067	-0.078	-1.083
MVPA	0.016***	2.989	-0.027*	-1.789
Love Sports	0.614***	6.851	0.290***	3.199
Walking Environment Quality	0.038	1.001	-0.022	-0.495

Perception				
Environmental Facilities Perception	0.105**	2.251	-0.062	-1.253
Richness of Sports Facilities	-0.102	-0.888	-0.110	-0.921
Community Safety	0.124***	3.115	0.106**	2.357
Community Attachment	0.492***	5.993	0.284***	3.339
Community Management Satisfaction	0.059	1.617	0.045	1.010
Number of chronic diseases	-0.698***	-5.710	-0.766***	-5.379
Age	-0.009	-1.068	0.002	0.208
Marital Status	0.119	0.818	0.260	1.600
Education	-0.208*	-1.717	0.420***	3.268
Social Stratum	-0.149**	-2.235	0.165**	2.185
Working State	0.408*	1.758	0.525***	2.664
Mental State	0.225***	3.055	0.477***	6.189
B	3.351***	4.385	2.996***	4.246
F	14.249		13.487	
Adjusted R^2	0.311		0.397	
Sig	0.000		0.000	

Notes: ***, **, * were significant at 0.01, 0.05 and 0.1 levels, respectively.

5.4 Conclusion and discussion

In this chapter, by establishing multiple regression equations, we empirically demonstrated the influence of built environment on residents' self-rated health. The main conclusions are as follows:

(1) The built environment had a certain influence on the self-rated health of residents. The influence was only reflected in land use mixedness, accessibility of living facilities and sports facilities. Compared with the influence of the built environment to physical activity, the influence factors were less . The direct influence of the objective characteristic of the built environment on self-rated health was not very significant. However, the influence was relatively stable and not affected by other factors such as social environment. Land use mixedness had no effect on both male and female. Catering facilities and road density had an influence on male, but not on female.

(2) The subjective perception of built environment had a significant influence on residents' self-rated health, mainly in two aspects: environmental quality perception and environmental facilities perception. But the influence of subjective perception was disturbed by social environment. Once social environment factors were added, the correlation of subjective perception was significantly reduced, or even showed no correlation. After controlling the number of individual chronic diseases, the influence of subjective perception had been improved. But subjective perception had no effect

on female's self-rated health. Only environmental facilities perception had a positive impact on male.

(3) Social environment had an important influence on residents' self-rated health. Community attachment had the most significant influence. Increasing the frequency of communication and deepening the level of communication, and improving community attachment can help to improve the health of residents. The influencing factors of the second level were community security and community management level awareness. Community safety was the basic demand of residents for leisure physical activity (Alfonzo, 2005) . It was generally believed that a good community built environment was conducive to residents' communication, monitoring, and enhancing the sense of community security. The level of community management was conducive to the maintenance of the built environment and the promotion of residents' communication through the organization of community activity, so as to enhance residents' community attachment and promote health of residents. Community security and community attachment also had significant positive correlation with male and female.

(4) As far as individual characteristics were concerned, the degree of love for sports and the time of leisure physical activity had a significant influence on residents' self-rated health. It can also be confirmed that physical activity plays a significant role in mediating the built environment and health. The influence of mental state on residents' self-rated health was very stable, not affected by other factors, and showed a significant positive correlation. Education had no effect on the whole sample analysis. The variables of gender, age, marital status, social stratum and working status had no stable effect on the self-rated health of residents, and were obviously affected by the added variables. But from the general trend, with the growth of age, the health of residents showed a downward trend; marriage was conducive to promoting health of residents; participation in social work was also conducive to promoting health of residents. The biggest difference between male and female lay in the influence of education and social stratum. These two variables were negatively correlated with male, but positively correlated with female.

5.5 Chapter summary

This chapter used the multiple regression method to analyze the impact of built environment on self-rated health. Firstly, five models were established to explore the independent influence, the influence after adding the characteristics of personal physical activity, the influence of the subjective perception, the influence of the social

environment , and the influence of the chronic disease controlled. The conclusion showed that the built environment and social environment have an influence on the self-rated health of residents. The subjective perception and social environment had more significant influence on residents' self-rated health. For the improvement of the built environment, we must pay attention to the use of people and build a space easy for people to communicate. Then the research establishes multiple regression model for the survey data of male and female respectively, and analyzes and compares the influence difference between male and female in the community environment and self-rated health. We can see that there are differences in the influence of built environmental factors, subjective perception and personal characteristics on self-rated health of male and female. Female were more affected by social environment and personal characteristics.

In the study, we found that the residents' mental state has a significant and stable impact on self-rated health. We will expand the scope of health in the later study. At the same time, in the previous research, we found that the objective characteristics, subjective perception, social environment, physical activity, physical health and mental health of the built environment have certain influence. We will further study the overall mechanism of the influence of community environment on health.

Chapter 6 - The influence path of built environment on health of residents

6.1 Introduction

The definition of health of the World Health Organization in 1946 extended human health from the biological significance to the mental and social relations, including the physical, mental, family and social life. Community environment includes natural environment, built environment and social environment. We mainly study the latter two aspects. The built environment mainly affects people's physical health by influencing their daily transportation and physical activity (Frank and Engelke, 2001). The development of Healthy City needs a tolerant and stable social environment and harmonious and peaceful interaction among the members of the society. In recent years, health geography, urban and rural planning and other multidisciplinary fields had focused on the influence of urban community environment on health of residents (Giles-Corti et al., 2016; Kwan, 2012; Lederbogen et al., 2011). Using the planning concept of Smart Growth, New Urbanism and Compact Development, western scholars believed that changing the built environment can effectively promote residents to adopt non motorized travel modes, actively participate in physical activity, increased neighborhood contact and social capital, and promoted physical and mental health (Ewing et al., 2014).

The modern way of life reduces people's physical activity, which leads to the increase of chronic diseases. Through the active intervention to the built environment, it can promote the increase of people's physical activity, thus promoting people's physical health. Most Western studies believe that improving land use compactness, increasing functional diversity, enhancing traffic accessibility, improving the accessibility of facilities, and improving street aesthetics are conducive to promoting physical activity (Smith et al al.2017; Karmeniemi, 2018). Physical activity can significantly promote the reduction of chronic diseases (Lu and Tan, 2015). As an important component of the built environment, the reasonable layout and good quality of public space can increase the opportunities for people to communicate with others, thus enhancing the structured social connections (such as social network and social integration), which are beneficial to people's mental and physical health (Michael, 2005; Szreter and Woolcock, 2004)

Community environment can affect the mental health of residents (Almedom, 2005; Bond et al, 2012; Lachowycz and Jones, 2013). Studies had shown that

crowded living conditions and poor air quality can lead to mental disorders (Evans et al., 2003). Among them, park green space, population density, public transport accessibility will have an important impact on mental health through influencing social community and physical activity (Sugiyama et al, 2018; de Vries et al., 2013; Francis et al., 2012), the green public space and fitness space with high density and high accessibility were helpful to promote the fitness activity and social activity of residents, so as to improve their mental health (Melis et al, 2015; Maas et al, 2006). However, the conclusions of related studies were inconsistent.

Some researchers were also exploring the relationship between social environment and mental health. Hämmig et al. believed that alienation of neighborhood will reduce personal well-being and cause negative effects on physical and mental health (Hansson et al, 2011; Hämmig et al, 2009). Tan et al. (2010) believed that people get huge benefits in emotion and body through interpersonal communication. On the contrary, the lack of normal social interaction often caused diseases such as cancer and depression. The study found that social integration, trust and willingness to help each other between neighbors were significantly related to self-rated mental health and depression (Araya et al, 2007; Bassett and Moore, 2013; Gilbert et al, 2013). According to psychology and sociology, participating in fitness activity together with neighbors helps individuals to establish a good social support network, promote neighborhood integration, and increase the community attachment, which was of positive significance for easing the tension and pressure accumulated in work and life (Chen et al, 2015; Zhang and Ta, 2009;). Qiu et al. (2019) studies showed that social interaction had a significant positive correlation with the level of mental health.

From the current research, there were relatively more studies on the unilateral influence of built environment on physical health or mental health. It was less to study the influence path between the built environment, social capital, physical and mental health. In addition, more research cases were concentrated in Europe and the United States, or China's Beijing, Shanghai and other developed regions, and lack of attention to other cities. Based on this, this chapter used structural equation model to study the influence path between built environment, social capital, physical health and mental health through the data of Fuzhou.

6.2 Method and variables

6.2.1 Analytical framework

This chapter attempted to explore the influence mechanism and path between

community environment and health. By combing the existing literature and combining with the actual situation of China, the following analysis framework was proposed (Figure 6-1).

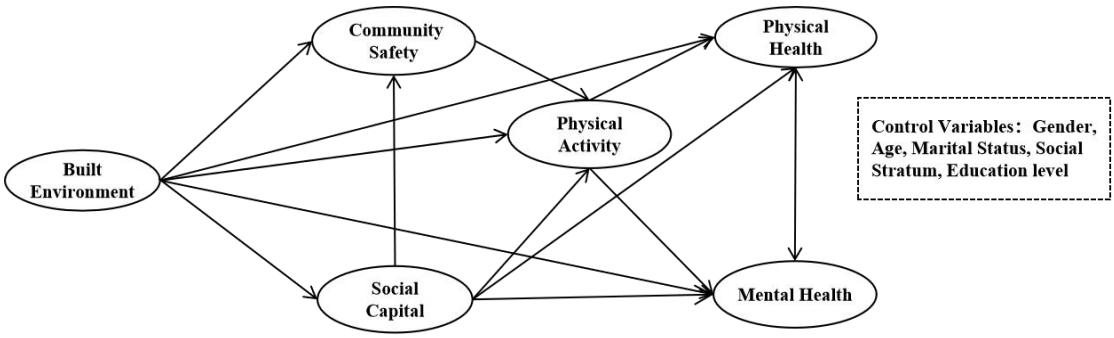

Figure 6-1 Research analysis framework

The research put forward the hypothesis of the influence path of community environment on health.

First, the built environment directly affects physical health and the built environment directly affects mental health.

Second, social capital directly affects physical health, and social capital directly affects mental health.

Third, physical activity plays an intermediary role. The built environment and social capital affect physical and mental health respectively through physical activity.

Fourth, social capital plays an intermediary role. The built environment influences physical and mental health through social capital. Physical health and mental health affect each other.

Fifth, community safety plays an intermediary role. The built environment and social capital affect physical activity and health respectively through community safety.

6.2.2 Method

In the research, the built environment was subdivided into three potential variables: density and diversity, road connectivity, and accessibility of sports facilities. A structural equation model was built to analyze the path linear relationship among the built environment, social capital, community safety, physical activity, physical health and mental health, as well as the influence mechanism among the variables through Amos software (Figure 6-2). Compared with the regression model of fragment analysis, structural equation model can further reveal the overall mechanism of community environmental characteristics on health.

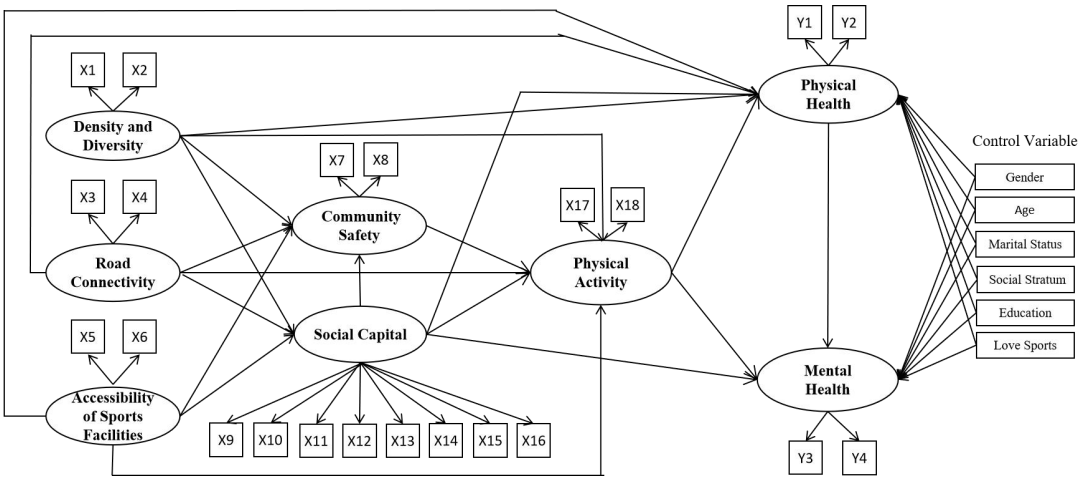

Figure 6-2 Structural equation model setting

6.2.3 Variables

Eight potential variables were identified in this study, including density and diversity, road connectivity, sports facilities accessibility, community safety, social capital, physical activity, physical health and mental health. Among them, social capital, community safety, physical activity as intermediary variables to consider its influence among various elements.

Density and diversity were observed from POI density and entropy index of land use. Road connectivity was observed from the density of main road network and branch network. The accessibility of sports facilities was observed from the proportion of POI and satisfaction of sports facilities. The social capital reflected the community communication by taking the level of neighborhood relationship as the observation variable. The research divided it into eight levels. This content has been described in Chapter 5.

Community safety was observed from public safety and traffic safety. Physical activity in the study mainly focuses on leisure physical activity. Physical activity was evaluated by two observation variables: the length of leisure walking and the length of moderate to vigorous physical activity. Both aimed at physical exercise, but they had different intensity. Two observation variables were used in physical health. Objective condition was observed by chronic disease or not; subjective evaluation was observed by self-evaluation of physical health. Mental health was observed from two aspects: the happy degree of community life and the frequency of depression in a month. Variables were measured by residents' self-rated (Table 6-1).

Control variables included gender, age, marital status, social stratum, education and other individual characteristics that may affect health.

Table 6-1 Statistics description of variables

Latent Variable	Observed Variable	Value Description	Mean Value	S.D.	Mean Value	S.D.	Mean Value	S.D.
Density And Diversity	X1 POI Density	Unit: 10000 / km^2	0.05	0.04	0.05	0.05	0.06	0.05
	X2 Land Use Entropy Index	EI=∑Si×ln(1/Si)	1.48	0.40	1.47	0.38	1.51	0.42
Road Connectivity	X3 Main Road Network Density	Unit:km/km^2	11.02	3.18	10.87	3.25	11.26	3.06
	X4 Branch Network Density	Ditto	7.84	2.66	7.78	2.61	7.94	2.73
Sports Facilities Accessibility	X5 Proportion of Sports Facilities POI	Unit：%	1.94	2.93	1.94	3.03	1.95	2.80
	X6 Richness of Sports Facilities	Very scarce=1 to Very rich=5	3.60	1.04	3.60	1.08	3.60	1.00
Community Safety	X7 Public Safety	Very worried=1 to Very not worried=10	7.14	2.10	7.17	2.07	7.09	2.17
	X8 Traffic Safety	Ditto	6.82	2.18	6.80	2.17	6.85	2.21
Social Capital	X9 Know Neighbors	Extremely inconsistent=1 to Very consistent=4	2.46	0.96	2.41	0.94	2.54	0.98
	X10 Borrow Tools	Ditto	2.78	1.00	2.70	1.00	2.89	0.99
	X11 Chat with Neighbors	Ditto	2.13	0.99	2.08	1.03	2.19	1.04
	X12 Borrow Money	Ditto	2.07	1.02	2.43	0.98	2.04	1.00
	X13 Trust Neighbors	Ditto	2.47	0.97	2.43	0.98	2.52	0.97
	X14 Similar Values	Ditto	2.30	0.94	2.22	0.91	2.42	0.98
	X15 Community for Help	Ditto	2.40	1.00	2.39	0.97	2.43	1.04
	X16 Rich Community activity	Ditto	2.20	0.98	2.18	0.96	2.22	1.02
Physical Activity	X17Leisure Walking	Unit: hour	4.46	6.45	4.73	7.13	4.03	5.08
	X18 MVPA	Ditto	3.04	8.99	3.89	10.98	1.73	4.06
Physical Health	Y1Self-Rated Health	Poor health=1 to Very healthy=10	7.13	1.79	7.20	1.87	7.04	1.66
	Y2Chronic Disease or not	Yes=0，No=1	0.83	0.37	0.84	0.37	0.82	0.38
Mental Health	Y3 Level of Happiness in Community Life	Very unhappy = 1 to Very happy = 5	3.69	0.70	3.67	0.69	3.67	0.69
	Y4 Frequency of Depression	Always depressed = 1 to Never depressed = 5	3.40	0.82	3.40	0.81	3.40	0.83
Control Variable	Gender	Male=0，Female=1	0.38	0.48	-	-	-	-
	Age	Unit：year	31.32	9.04	31.82	9.05	30.54	8.98
	Marital Status	Unmarried=0，Married=1	0.65	0.48	0.63	0.48	0.68	0.47
	Social Stratum	Lowest layer=1~Topmost=5	2.45	0.90	2.45	0.92	2.46	0.88
	Education	No higher education=0，Higher education=1	0.46	0.50	0.39	0.49	0.58	0.49

6.3 Results

6.3.1 Influence path of community environment on health in all samples

According to the structural equation model of all samples, community safety, social capital and physical activity all played a role in the process of environmental influence on health. However, there were different path relationships. The direct effect of each variable is shown in Table 6-2. The influence path is shown in Figure 6-3.

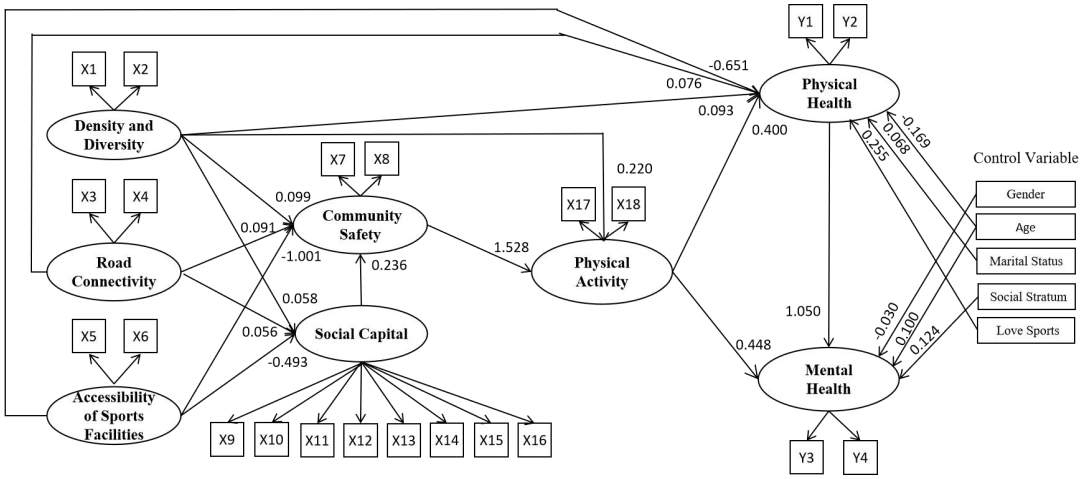

Figure 6-3 Influence path of built environment on health

First, the built environment had a direct influence on the physical health of residents. The space formed by density and diversity, road connectivity and accessibility of sports facilities promotes the physical health of residents. Road accessibility had the greatest influence on health.

Second, only density and diversity in the built environment directly affected physical activity. The suitable urban environment with comprehensive development density and function was conducive to promoting the development of leisure physical activity. The influence of road connectivity and the accessibility of sports facilities on physical activity was not significant.

Third, the built environment will had an influence on the social capital. A good built environment can provide a public space to promote community interaction, and then increase the opportunities for neighborhood interaction. The increase of community communication was conducive to the cultivation of neighborhood trust and community attachment. Therefore, community communication should be actively built to promote the communication of residents. Social capital had no direct influence on physical and mental health. It indirectly affected physical health and mental health through residents' safety perception and physical activity.

Fourth, the built environment will have an influence on urban safety. Density and diversity, road connectivity, sports facilities will affect community safety perception. Among them, the accessibility of sports facilities had the greatest influence on community safety perception. The sense of community security can promote residents' sports activities. Physical activity helped to promote physical and mental health of residents. Strengthening physical exercise was beneficial to the physical and mental health of residents.

Fifth, the physical health of residents had a significant positive influence on mental health. The mental health level of healthy residents was higher. That was to say, the more healthy the general physiology was, the better the mental health was. We used this model, did not change other elements, only changed the path direction of mental health and physical health, and examined the path of mental health on physical health. The results showed that the effect of mental health on physical health was not visible in this model.

Sixth, from the perspective of control variables, gender and age had an influence on physical and mental health. But it had a negative influence on physical health and a positive influence on mental health. Generally, famale's mental health was better than male's, and male's physical health was better than female's. Marital status and love of sports were conducive to the physical health of residents, but had no significant influence on mental health. Social stratum had no significant effect on physical health, but had a significant positive effect on mental health. The higher the social stratum, the better the mental health. Education level had no significant effect on health.

Table 6-2 Analysis results of structural equation model of all samplers

			Estimate	S.E.	Standardized Estimate
Social Capital	<---	**Density And Diversity**	1.556**	0.785	0.058
Social Capital	<---	**Road Connectivity**	0.019**	0.008	0.056
Social Capital	<---	**Sports Facilities Accessibility**	-3.047**	1.437	-0.493
Community Safety	<---	**Density And Diversity**	6.194***	2.043	0.099
Community Safety	<---	**Road Connectivity**	0.070***	0.020	0.091
Community Safety	<---	**Sports Facilities Accessibility**	-14.283**	6.603	-1.001
Community Safety	<---	**Social Capital**	0.545**	0.226	0.236
Physical Activity	<---	**Community Safety**	3.087*	2.217	1.528
Physical Activity	<---	**Social Capital**	-1.163	1.785	-0.249
Physical Activity	<---	**Density And Diversity**	27.780*	16.780	0.220
Physical Activity	<---	**Road Connectivity**	0.085	0.178	0.055
Physical Activity	<---	**Sports Facilities Accessibility**	-48.620	43.209	-1.686
Physical Health	<---	**Physical Activity**	0.128***	0.032	0.400
Physical Health	<---	**Social Capital**	.083	0.109	0.055
Physical Health	<---	**Density And Diversity**	3.743***	1.287	0.093
Physical Health	<---	**Road Connectivity**	0.038***	0.013	0.076

			Estimate	S.E.	Standardized Estimate
Physical Health	**<---**	**Sports Facilities Accessibility**	-6.011**	2.747	-0.651
Physical Health	**<---**	**Gender**	-0.050	0.084	-0.083
Physical Health	**<---**	**Age**	-0.020***	0.005	-0.169
Physical Health	**<---**	**Marital Status**	0.152**	0.086	0.068
Physical Health	**<---**	**Social Stratum**	0.010	0.046	0.008
Physical Health	**<---**	**Education**	0.043	0.083	0.020
Physical Health	**<---**	**Love for Sports**	0.361***	0.044	0.255
Mental Health	**<---**	**Physical Activity**	0.057***	0.012	0.448
Mental Health	**<---**	**Social Capital**	-0.018	0.037	-0.012
Mental Health	**<---**	**Gender**	0.087**	0.039	-0.030
Mental Health	**<---**	**Age**	0.006***	0.002	0.100
Mental Health	**<---**	**Marital Status**	-0.032	0.039	-0.037
Mental Health	**<---**	**Social Stratum**	0.058***	0.021	0.124
Mental Health	**<---**	**Education**	0.017	0.037	0.021
Mental Health	**<---**	**Love for Sports**	0.235	0.041	0.129
Mental Health	**<---**	**Physical Health**	0.397***	0.039	1.004
POI Density	**<---**	**Density And Diversity**	1.000	-	0.540
Land Use EI	**<---**	**Density And Diversity**	14.589***	5.470	0.969
Main Road Network Density	**<---**	**Road Connectivity**	1.000	-	0.674
Branch Network Density	**<---**	**Road Connectivity**	1.457***	0.369	1.174
Proportion of Sports Facilities POI	**<---**	**Sports Facilities Accessibility**	1.000	-	0.069
Richness of Sports Facilities	**<---**	**Sports Facilities Accessibility**	-3.664**	165.591	-0.404
Public Safety	**<---**	**Community Safety**	1.000	-	0.781
Traffic Safety	**<---**	**Community Safety**	1.118***	0.053	0.842
Know Neighbors	**<---**	**Social Capital**	1.000	-	0.745
Borrow Tools	**<---**	**Social Capital**	1.071***	0.038	0.763
Chat	**<---**	**Social Capital**	1.188***	0.038	0.852
Borrow Money	**<---**	**Social Capital**	1.188***	0.039	0.830
Trust neighbors	**<---**	**Social Capital**	1.140***	0.037	0.833
Similar Values	**<---**	**Social Capital**	1.088***	0.036	0.821
Community for Help	**<---**	**Social Capital**	0.856***	0.039	0.610
Rich Community Activity	**<---**	**Social Capital**	0.889***	0.038	0.644
MVPA	**<---**	**Physical Activity**	1.000	-	0.370
Leisure Walking	**<---**	**Physical Activity**	1.139***	0.202	0.590
Self-Rated Health	**<---**	**Physical Health**	1.000	-	0.592
Chronic Disease or not	**<---**	**Physical Health**	0.119***	0.013	0.338
Happy Degree	**<---**	**Mental Health**	1.000	-	0.762
Degree of Depression	**<---**	**Mental Health**	0.885***	0.079	0.458
			CMIN=2645.372, df=299, CMIN/DF=8.847		RMSEA=0.055, NFI=0.792, TLI=0.759, CFI=0.809

Notes: ***, **, * were significant at 0.01, 0.05 and 0.1 levels, respectively.

6.3.2 Influence path of community environment on health in male

According to the male sample data, the influence path of community environment on health is shown in Figure 6-4. There were significant differences in the influence paths between male and the all sample. Although community safety, social capital and physical activity still played an intermediary role, the influence path had changed. The direct influence of the built environment on physical health decreased significantly. Density and diversity had no significant effect on male, it had no direct or indirect effect. The direct influence of road connectivity also disappeared. Social capital had a significant direct influence on physical health.

There were three main paths. First, the accessibility of sports facilities directly affected the physical health of male. The number and conditions of sports facilities should be paid attention to in community planning and construction. The second was that the influence of road connectivity and sports facilities accessibility on the social capital. Social capital directly affected physical health. For male, built environment can promote social interaction. Social interaction of community neighbors was beneficial to physical health. The third was that the road connectivity and the accessibility of sports facilities had an influence on community safety. Streets with strong connectivity and communities with high accessibility of sports facilities were easy to attract more people to participate in community activity. More people will enhance the sense of security in the community. The sense of community security was conducive to promoting physical activity of residents. This was a mutually reinforcing role. Because more people flowed and made the community feel safer, it will encourage more people to engage in physical activity and for longer periods of time in the community and the community will be safer. Physical activity can promote the physical and mental health of residents. Physical health contributes to the mental health of residents.

Among the control variables, age only affected physical health. Social stratum, education and love of sports had an influence on physical and mental health, and the influence was the opposite. See Table 6-3 for the influence coefficient between variables.

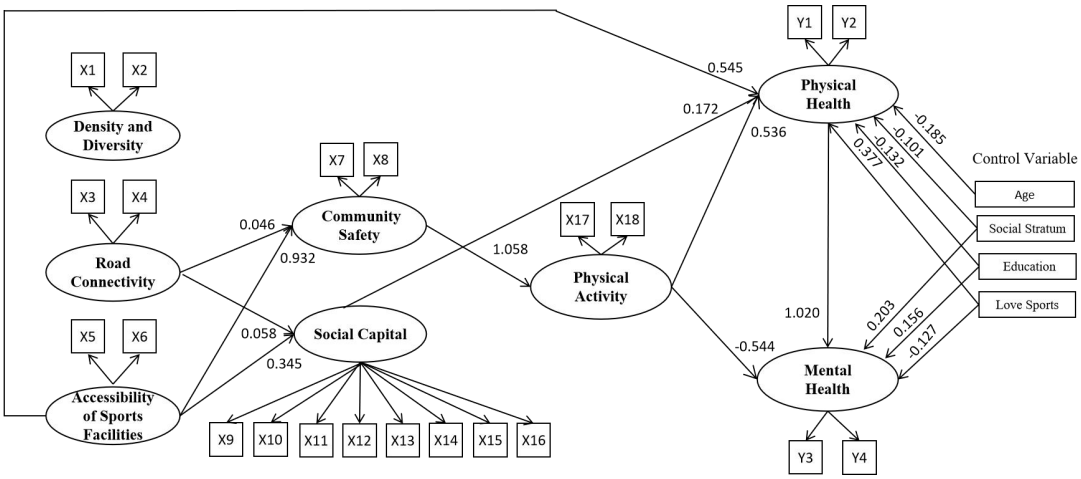

Figure 6-4 Influence path of community environment on male's health

6.3.3 Influence path of community environment on health in female

According to the sample data of female. See Figure 6-5 for the influence path of community environment on health. The female's path of influence was similar to that of all samples, but different from that of male. Compared with the all sample, there were three main changes in the female sample. First, the influence of road connectivity on social capital was insignificant. The improvement of road connectivity did not significantly promote femal's community interaction. Second, physical activity was not significant for promoting mental health. The optimization of built environment can be conducive to the development of community communication and the improvement of community security, thus promoting the increase of physical activity, improving the physical health, and then improving the mental health. However, the development of physical activity can not directly improve female's mental health. Third, in the control variables, marital status, social stratum, education, love of sports had an influence on female's physical health. But individual characteristic variables were not related to mental health. The influence coefficient between variables is shown in Table 6-3.

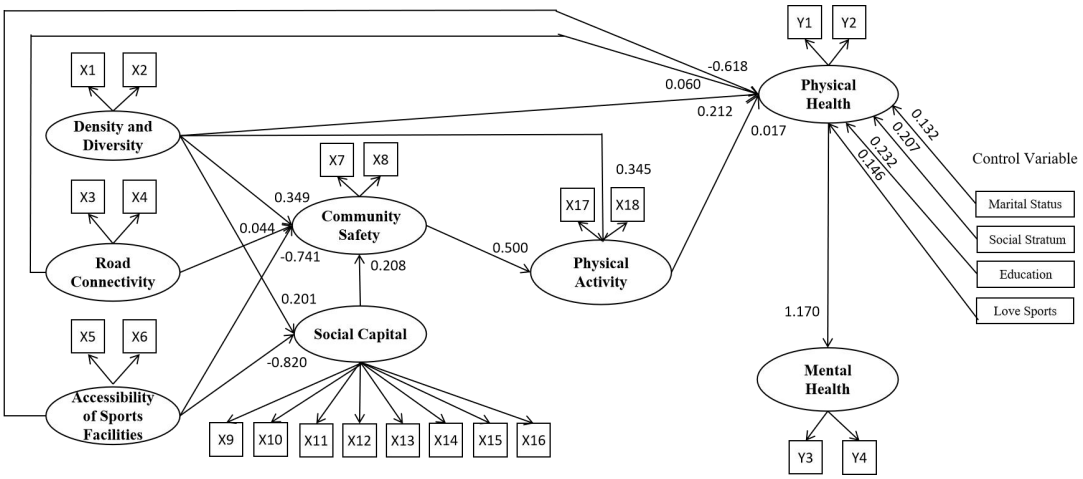

Figure 6-5 Influence path of community environment on female's health

Table 6-3 Path results of structural equation of male and female samples

			Male			Female		
			Estimate	S.E.	Standardized Estimate	Estimate	S.E.	Standardized Estimate
Social Capital	<---	**Density And Diversity**	-0.289	0.892	-0.041	4.223***	1.180	0.201
Social Capital	<---	**Road Connectivity**	0.025***	0.009	0.058	-0.001	0.010	-0.002
Social Capital	<---	**Sports Facilities Accessibility**	0.970*	0.547	0.345	-0.820***	0.311	-0.520
Community Safety	<---	**Density And Diversity**	-0.418	1.310	-0.028	17.758***	3.569	0.349
Community Safety	<---	**Road Connectivity**	0.041**	0.019	0.046	0.059**	0.029	0.044
Community Safety	<---	**Sports Facilities Accessibility**	5.604*	2.916	0.932	-2.831***	1.072	-0.741
Community Safety	<---	**Social Capital**	0.100	0.194	0.047	0.504*	0.290	0.208
Physical Activity	<---	**Community Safety**	2.920**	3.075	1.058	0.634**	0.283	0.500
Physical Activity	<---	**Social Capital**	1.001	0.965	0.170	-0.089	0.476	-0.029
Physical Activity	<---	**Density And Diversity**	-1.538	5.088	-0.037	22.278**	8.859	0.345
Physical Activity	<---	**Road Connectivity**	0.051	0.157	0.020	-0.059	0.051	-0.034
Physical Activity	<---	**Sports Facilities Accessibility**	18.316	22.275	1.104	-2.053	1.649	-0.424
Physical Health	<---	**Physical Activity**	0.146***	0.036	0.536	0.009**	0.055	0.017
Physical Health	<---	**Social Capital**	0.277**	0.129	0.172	-0.062	0.167	-0.038
Physical Health	<---	**Density And Diversity**	-0.074	0.290	-0.007	7.366***	2.371	0.212
Physical Health	<---	**Road Connectivity**	0.002	0.012	0.002	0.055**	0.023	0.060
Physical Health	<---	**Sports Facilities Accessibility**	2.465*	1.280	0.545	-1.610***	0.587	-0.618

			Male			Female		
			Estimate	S.E.	Standardized Estimate	Estimate	S.E.	Standardized Estimate
Physical Health	**<---**	**Age**	-0.023***	0.006	-0.185	-0.007	0.007	-0.049
Physical Health	**<---**	**Marital Status**	-0.022	0.110	-0.010	0.349***	0.133	0.132
Physical Health	**<---**	**Social Stratum**	-0.121**	0.058	-0.101	0.291***	0.071	0.207
Physical Health	**<---**	**Education**	-0.298***	0.109	-0.132	0.579***	0.126	0.232
Physical Health	**<---**	**Love for Sports**	0.586***	0.076	0.377	0.232***	0.083	0.146
Mental Health	**<---**	**Physical Activity**	-0.059***	0.017	-0.544	-0.002	0.003	-0.067
Mental Health	**<---**	**Social Capital**	0.013	0.055	0.021	0.002	0.008	0.024
Mental Health	**<---**	**Age**	0.005	0.003	0.100	-0.002	0.001	-0.297
Mental Health	**<---**	**Marital Status**	0.053	0.052	0.058	0.023	0.017	0.194
Mental Health	**<---**	**Social Stratum**	0.098***	0.028	0.203	0.005	0.007	0.072
Mental Health	**<---**	**Education**	0.142***	0.054	0.156	0.026	0.019	0.236
Mental Health	**<---**	**Love for Sports**	-0.098*	0.059	-0.127	0.012	0.010	0.162
Mental Health	**<---**	**Physical Health**	0.408***	0.058	1.020	0.052	0.032	1.170
POI Density	**<---**	**Density And Diversity**	1.000		1.993	1.000		0.734
Land Use EI	**<---**	**Density And Diversity**	0.999	2.904	0.257	8.519***	1.363	0.723
Main Road Network Density	**<---**	**Road Connectivity**	1.000		0.495	1.000		0.438
Branch Network Density	**<---**	**Road Connectivity**	2.591	2.055	1.599	3.686	4.236	1.809
Proportion of Sports Facilities POI	**<---**	**Sports Facilities Accessibility**	1.000		0.081	1.000		0.170
Richness of Sports Facilities	**<---**	**Sports Facilities Accessibility**	1.911**	0.974	0.434	-1.014***	0.345	-0.480
Public Safety	**<---**	**Community Safety**	1.000		0.709	1.000		0.840
Traffic Safety	**<---**	**Community Safety**	1.278***	0.087	0.863	1.047***	0.078	0.862
Know Neighbors	**<---**	**Social Capital**	1.000		0.732	1.000		0.762
Borrow Tools	**<---**	**Social Capital**	1.091***	0.052	0.749	1.039***	0.056	0.784
Chat	**<---**	**Social Capital**	1.209***	0.050	0.861	1.152***	0.058	0.830
Borrow Money	**<---**	**Social Capital**	1.311***	0.053	0.869	1.034***	0.056	0.775
Trust neighbors	**<---**	**Social Capital**	1.192***	0.050	0.837	1.073***	0.054	0.828
Similar Values	**<---**	**Social Capital**	1.069***	0.047	0.801	1.108***	0.054	0.851
Community for Help	**<---**	**Social Capital**	0.843***	0.051	0.596	0.881***	0.060	0.633

			Male			Female		
			Estimate	S.E.	Standardized Estimate	Estimate	S.E.	Standardized Estimate
Rich Community Activity	**<---**	**Social Capital**	0.907***	0.050	0.649	0.875***	0.059	0.640
MVPA	**<---**	**Physical Activity**	1.000		0.369	1.000		0.565
Leisure Walking	**<---**	**Physical Activity**	0.964***	0.201	0.547	1.169***	0.358	0.528
Self-Rated Health	**<---**	**Physical Health**	1.000		0.588	1.000		0.765
Chronic Disease or not	**<---**	**Physical Health**	0.130***	0.016	0.390	0.079***	0.017	0.256
Happy Degree	**<---**	**Mental Health**	1.000		0.806	1.000		0.080
Degree of Depression	**<---**	**Mental Health**	0.680***	0.102	0.370	-7.150*	4.317	-0.479
			CMIN=1479.376, df=164, CMIN/DF=9.021		RMSEA=0.082, NFI=0.770, TLI=0.739, CFI=0.796	CMIN=1215.821, df=275, CMIN/DF=4.421		RMSEA=0.066, NFI=0.769, TLI=0.756, CFI=0.808

Notes: ***, **, * were significant at 0.01, 0.05 and 0.1 levels, respectively.

6.4 Conclusion and discussion

In this chapter, structural equation method was used to study the impact path of built environment on health. The main conclusions are as follows:

First, density and diversity, road connectivity and sports facilities accessibility can directly affect the physical health of residents. But at the same time, these factors will also affect the physical and mental health of residents through the intermediary role of social capital, community safety and physical activity.

Second, the intermediary role of community security was obvious. The built environment can directly affect the community safety perception, and it can also affect the community safety perception through the influence on the social capital.

Third, physical activity, as an intermediary factor, plays an important role in the influence of community environment on health of residents. The density and diversity of the built environment directly affected physical activity. The built environment can also indirectly affect physical activity through social capital and community safety. Physical activity not only promotes the physical health of residents, but also benefits the mental health of residents. Physical activity can cultivate mental quality, such as will quality, endurance and self-confidence, and helped to eliminate people's tension and depression (Jayakody et al, 2014; Brown et al, 2013; Biddle and Asare, 2011), which was good for residents' mental health.

Fourth, for male, the influence path was quite different. Density and diversity had no direct or indirect effects on male health. Road connectivity and sports facilities

accessibility can affect physical activity through community safety, and then affect physical and mental health of male. Road connectivity and sports facilities accessibility can also directly affect physical health through the role of social capital. Social capital had no influence on male community safety perception and mental health. For female, the influence path of the built environment on health was similar to that of the all sample.

Fifth, As far as individual characteristics were concerned, age, gender, marriage status, social stratum and education level all had different effects on all samples, male and female.

6.5 Chapter Summary

From the conclusion, we can see that the improvement of community environment can intervene the health of residents. Although the health of residents will be affected by personal characteristics, the built environment can affect the physical and mental health of residents through different intermediary factors. There were significant differences in the influence path of health between male and female in the community environment. In the construction of a healthy city, we should not only pay attention to the proper density of the built environment, the mixture of functions, the convenience and comfort of facilities and other hardware issues, but also pay attention to the construction of the community software environment, promote neighborhood communication, organize rich community activity, and enhance residents attachment. We should not only pay attention to the physical health but also the mental health of the residents. At the same time, we should pay special attention to the needs of different groups of male and female.

Chapter 7 - Conclusions

7. 1 Conclusions

In this dissertation, the multiple regression model and structural equation model were used to analyze the impact of community built environment on health of residents. The research was based on the open network data and social survey data of Fuzhou City, using SPSS and Amos software, and based on the community scale. The results are as follows:

First of all, the built environment had an influence on the traffic walking activity and leisure walking activity. Although traffic walking was a necessary activity of life, it was less affected by external factors such as individual characteristics. However, the factors related to the built environment still had a significant influencc on the traffic walking activity. The diversity of urban land use made residents less dependent on mobile traffic when carrying out necessary activity, more willing to choose the way of walking, thus promoting the traffic walking activity of residents. The increase of commercial facilities, living service facilities and catering facilities will also promote the traffic pedestrian activity of residents. The built environment had less direct influence on leisure walking activity, including only functional mix, branch density and sports facilities accessibility. The community with mixed functions and convenient sports facilities were more conducive to promoting residents' leisure walking activity. However, too much urban density was not conducive to the development of leisure physical activity. This was determined by the characteristics of high urban construction density in China, which was different from the conclusion of North American sprawling cities. Too high branch density was not conducive to physical activity, which was due to the fact that the respondents mostly choose to carry out physical activity in the residential area, and the smaller branch density will make the residential area too small to provide a comfortable activity site. Community safety, community life satisfaction will also affect the leisure walking activity of residents. Individual characteristics also had a significant influence on leisure physical activity. the built environment acted on moderate to vigorous physical activity through subjective perception. Security perception played a mediating role. The subjective POI density, subjective sports facilities, commercial facilities, the beauty of the environment and the community safety were all conducive to promote moderate to vigorous physical activity of the residents in the community.

Second, the built environment and social environment had an influence on residents' self-rated health. The function mixing degree, the convenience of living

service facilities, the convenience of sports facilities, the convenience of public transport stations all had an influence on the self-rated health of residents. Subjective perceptions such as environmental quality perception and environmental facilities perception also had an influence on residents' self-rated health. Social environment, such as community security, community attachment, community management satisfaction also had an influence. The built environment affected the health of residents through four paths. First, the built environment factors directly affected the physical health of the residents, and the physical health can affect the mental health. The second was that the built environmental factors affected the physical activity through the intermediary role of community safety, and then affected physical and mental health. The third was that the built environment affect community social interaction, then affected community safety perception, then affected physical activity, and finally affected physical and mental health. A good built environment provided public space for social interaction, facilitates the development of social activity, promotes the shaping of the community human environment, and enhanced the residents' sense of community attachment, which was more conducive to the development of leisure physical activity, physical and mental health of residents. Fourth, the density and diversity of the built environment will directly affect the degree of physical activity of residents, and then affect the physical and mental health.

Third，it was found that the influenc of built environment factors on male's and female's physical activity and health were quite different. For traffic walking activity, male and female had opposite effects on function mixing, facilities accessibility and travel mode. There were significant differences in the influence of road density, education and monthly income. For leisure walking activity, there were opposite effects on population density, accessibility of green space facilities and monthly income. There were still significant differences in POI density, functional mix, facility accessibility, life satisfaction, age and marriage. For male, the objective characteristics of the built environment had less influence on subjective perception, only in the perception of environmental facilities. The potential variables of built environment had a direct influence on the moderate to vigorous physical activity and community safety. the influence path of health of built environment was quite different. Density and diversity had no direct or indirect effects on male health. Road connectivity and sports facilities accessibility can affect physical activity through community safety, and then affect physical and mental health of male. It can also directly affect physical health through the role of social capital. Social capital had no influence on community safety perception. For female, the objective characteristics of the built environment had an influence on subjective perception, but not directly

affected the moderate to vigorous physical activity. The intermediary role of community safety was significant. The influence path of the built environment on health was similar to that of the all sample.

According to the research conclusion, we put forward the following suggestions for the planning, design and construction management of Healthy City:

1. Improve the mixing of urban land use functions and the accessibility of public service society, and promote residents to carry out more walking activities. The mixed functions of urban land can make all kinds of facilities have similar accessibility within a certain range, and also help to comprehensively improve the accessibility of all kinds of facilities.

2. Increase the construction of green parks and sports facilities. On the one hand, green space and sports facilities can provide a place for physical activities of residents, which is conducive to promoting the development of physical activities, thus promoting physical health. On the other hand, green space and sports facilities are often the carriers of social interaction. The establishment of facilities is conducive to increase the opportunities of social interaction and relieve the psychological pressure of residents.

3. The design of the built environment must pay attention to the residents' subjective perception, and design based on the needs of human activities and human feelings. At the same time, we should also pay attention to the management of environmental facilities after completion

4. We should improve the level of community management, organize community activities and increase community communitation.

5. We should pay attention to the improvement of community safety. First, in environmental design, the space easy to communicate is often conducive to residents' safety perception. Second, reduce crime through management.

7.2 Further research

The influence path of built environment on health is complex. Due to various reasons, there are still deficiencies.

First, the urban built environment is complex, reflecting a lot of built environment and social environment elements. In view of the limitations of survey data, the selection of relevant elements has certain limitations, and it is difficult to fully reflect the influence of built environment. The factors of each element of the built environment can be further studied and determined.

Second, the social survey data mainly rely on the subjective cognition of the

respondents, who may overestimate or underestimate their sports time and other data. At the same time, the time of social survey is from June to July, the temperature of Fuzhou is in the hot stage in summer, and the self-assessment data provided by residents are affected by the temperature comfort. This will lead to some problems in the quasi determination of data. At the same time, the survey data adopts the network mode, which will also lead to the accuracy problem of the data due to the cognitive error.

Third, the research mainly focuses on correlation analysis and part of horizontal research, but also lack of in-depth horizontal and vertical research.

Fourth, The reference significance of the research results is limited due to the particularity of the city.

In the future research, I will further deepen in the following aspects.

The first is to make a further comparative study on different groups. The study will further select different types of communities and different groups to analyze the impact of built environment on health. So that it can more accurately determine the different effects of the elements of the built environment on health.

The second is to conduct more accurate research on some built environment factors. Guide the environmental design through relatively accurate indicators.

The third is to further study the needs of femele on built environment.

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