A Research Framework of Urban Spatial Planning Regulation Based on Cardiovascular Health in the Context of Severe Cold Climate

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Abstract: Climate has a significant impact on public health. In the context of severe cold climate, severe cold regions have high incidence of cardiovascular diseases. Combining the health problems with regional climate and urban spatial elements, to study the impact of urban space has on public health and planning regulation strategies will help deepen research of healthy urban planning. In this paper, with the analysis of the correlation between severe cold climate, urban space and cardiovascular, we discuss the research significance on urban spatial planning regulation based on cardiovascular health. We try to develop a research framework of urban spatial planning regulation in severe cold regions, through two pathways including reduction of incidence of cardiovascular diseases and promotion of physical activities favorable to prevention and rehabilitation of cardiovascular diseases. With the pathways analysis, preliminary planning regulation strategies are put forward, aiming at providing some support for healthy urban planning in severe cold regions for reducing the risk of cardiovascular diseases.

Keywords: severe cold region; cardiovascular health; urban space; planning regulation

Introduction

Cardiovascular health is the important cornerstone of human health. World Health Organization has reported that about 17.1 million people die of cardiovascular diseases in the world each year, accounting for 29% of all deaths. Chinese Cardiovascular Diseases Report (2017) showed that China had 290 million cardiovascular patients, and cardiovascular disease death ranked the first place of total death of urban and rural residents, higher than that of cancer and other diseases, causing over 40% of residents disease death (Chen W. W. *et al*, 2018). In addition, the elderly are the main sufferers. Relevant studies propose that the elderly have as 2~4 times incidence as non-elderly in hypertension, ischemic cardiovascular disease, atrial fibrillation and coronary heart disease (Geng J.C. and Jian H., 2009; Chen L. *et al*, 2018). According to the statistics published by National Office for Ageing, having stepped into an aging society, China had about 240 million aging population, accounting for 17.3% of the total population in 2017 and the proportion is predicted to reach 34.1% by 2050. In face of the significant public health problem threatening life and health and healthy aging, it is urgent to promote the prevention and treatment of cardiovascular diseases.

Climate has a close relationship with health.The significant impact on public health caused by climate should not be ignored. A large number of studies have found that cardiovascular disease morbidity and mortality are higher in high latitude and cold regions and in winter (Bhatnagar A., 2017). According to the International Association of Cold Cities, there are at least 30 countries located in the northern hemisphere, and more than 0.6 billion people have the life experiences in winter (Jiang C. Y. and Leng H., 2017). How to overcome the influence of climate factors to promote public health in the severe cold regions where cardiovascular health problems are more serious is a key point for prevention and treatment of cardiovascular diseases with regards to both China and the vast cold cities of the world.

A core content of social–ecological models published by World Health Organization is that urban space is an important factor influencing public health through affecting human behaviour, which reveals that reduction of the risk of illness in a larger population may come true by optimizing urban space (Sarkar C. *et al*, 2013). Applying this content to urban space and cardiovascular health, research by Diez-Roux A. V. has showed the correlation between neighbourhood environment and coronary heart disease (CHD) (Diez-Roux A. V., 2001); approaching green space has a significant influence on reducing cardiovascular mortality (Mitchell R. and Popham F., 2008; Shen Y. S. and Lung S. C.,2016); Gan proposed automobile exhaust exposure has a link with the arising of incidence of coronary heart disease(Gan W. Q. *et al*, 2010). Relative studies also show that there is a relationship between residential environment, such as sports facilities as well as quality of leisure activity area, and physical activities; thus residential environment may influence physical activities, further having impact on cardiovascular health (Kohl and Harold W., 2001; Humpel N. *et al*, 2002). Previous studies have revealed the potential relationship between urban space and cardiovascular health.

In this paper, focusing on cardiovascular health problems in the context of severe cold climate, we expect to explore urban spatial planning regulation strategies. On the basis of the analysis of correlation between severe cold climate, urban space and cardiovascular, we illustrates the significance, pathways and methods of urban space planning regulation research based on cardiovascular health in the context of severe cold climate, aiming at providing some theoretical basis and practical guidance for healthy urban planning in severe cold regions for reducing the risk of cardiovascular diseases.

1. Severe cold climate, urban space and cardiovascular health

1.1. Severe cold climate and cardiovascular health

Medical studies support the evidence that severe cold climate affects cardiovascular health. There is a u-shaped relationship between air temperature and cardiovascular mortality- for every one-degree decrease in air temperature in cold regions, cardiovascular mortality increases by 1% (Liu Z. X., 2013). The effects can be illustrated to be direct and indirect. In terms of the direct effects, the outdoor low-temperature environment and the sudden change in temperature between indoor and outdoor space are the key factors influencing cardiovascular health. Low-temperature exposure can result in vasoconstriction, spasm, hypoxia, blood viscosity increase, and increase the burden of the heart. The sudden change in temperature between indoor and outdoor space easily lead to rapid expansion and contraction of blood vessels in the process of indoor and outdoor transformation, resulting in increased vascular resistance and brittleness, which is the key cause of hypertension, coronary heart disease, stroke and other cardiovascular diseases (Hasegawa F. X., 1985). In terms of the indirect effects, severe cold climate can exert effects on cardiovascular health through its influence on urban environment and residents' behavior and activity patterns. In relationship with the long period of coal-burning heating as well as the ascending proportion of vehicle out-driving in severe cold regions in winter, the frequent occurrence of haze and the increase of atmospheric pollutants can cause damage

to human cardiovascular system. Meanwhile, the severe cold climate makes the residents in these regions develop dietary and living habits which are different from those in other regions, such as high-salt diet, less outdoor activities and physical exercise, and overweight or obesity resulting from excess fat metabolism. A number of key risk factors lie in the regional environment and residents' lifestyle in the sever cold regions. On the other hand, it should be noted that medical studies have shown the importance and necessity of appropriate outdoor exercise in winter for the prevention and rehabilitation of cardiovascular diseases, which indicates that severe cold weather has a dual effect on cardiovascular health.

1.2. Urban space and cardiovascular health

According to existing research, urban space is associated with cardiovascular risk factors (such as obesity and lack of exercise) and cardiovascular rehabilitation factors (such as heart-healthy walking activities). For example, more than 60 studies suggest the relationship between urban space and obesity; a number of features of communities in urban space have been proved to relate to BMI; communities with more physical activity resources are associated with lower insulin resistance levels (Li J. and Siegrist J., 2012).

In addition, specific to the impact mechanism, studies have shown that urban space may have an effect on cardiovascular health by affecting air environment, physical activity, social interaction, food intake and so on. In terms of air environment, studies have confirmed that urban space is related to the reduction of air pollution (Alonso R. *et al*, 2011; Rao M. *et al*, 2014), and several studies have linked air pollution to an increasing incidence of cardiovascular diseases (Metzger K. B. *et al*, 2004; Feng J. and Yang W., 2012). In terms of physical activities, lots of studies have shown the correlation between spatial elements such as green space and physical activities, while the correlation between physical activity level and cardiovascular risk has been widely confirmed (Li J. and Siegrist J., 2012). In terms of social interaction, some studies have shown that urban space is positively correlated with social support level, and a large number of studies have found that low social support level is one of the risk factors for cardiovascular diseases. In terms of food intake, the consumption and supply distribution of food in urban space will also affect residents' diet, which is closely related to cardiovascular health (Chum A. *et al*, 2013). Therefore, air environment, physical activity, social interaction and food intake mediate the impact of urban space on cardiovascular health, and the differences in urban space are important factors leading to the differences in cardiovascular health status.

1.3. Urban space and cardiovascular health in the context of severe cold climate

Under the direct effects of severe cold climate on human cardiovascular system and the indirect effects on urban environment and residents' lifestyle, residents are at higher risk of diseases due to factors consisting of the stimulation of cold air, increasing air pollutants, insufficient physical activities and social interaction in winter, as well as high-salt diet. Research from Huang Likun et al indicated that under the influence of urban 6-month-heating period in winter, cities in severe cold regions of China have higher concentration of suspended particulates and extremely serious air pollution (Huang L. K. *et al*, 2011). Introducing the existing survey, Yang Baofeng proposed that due to the long winter in northern China, residents have less time for outdoor activities, and almost 80.5% of them never exercise (Yang B. F., 2015). A statistical survey conducted by the Food and Nutrition

Advisory Steering Committee of Heilongjiang Province showed that the average daily salt intake of urban and rural residents aged 18 years and over was 10.6 g per person in the province, which exceeded the recommended daily intake limit of 76.7% in the Dietary Guidelines for Chinese Residents (Chen K. *et al*, 2015).

In view of the mediating factors of the impact of urban space on cardiovascular health, existing studies have provided evidential support and realistic plans for optimizing urban air quality in winter and promoting residents' physical activity in winter through urban space variously. For instance, Kong Fanqiu et al studied urban space optimization in cold regions based on air quality analysis in winter (Kong F. Q. *et al*, 2018). Tucker P. and Gilliland J. reviewed the literature about the participation of people in different age groups in sports activities in cold regions (Tucker P. and Gilliland J., 2007). Leveratto J.and Maria studied the morphological scale of buildings surrounding the open space, aiming at improving the comfort and utilization rate (Leveratto J.and Maria, 2002) .

Previous studies provide a theoretical basis to clarifying effects of severe cold on cardiovascular health, and revealing the possibility of optimizing intermediate factors through urban planning and design for reducing risk of cardiovascular diseases. However, research combining climate, urban space and cardiovascular health remains to be explored; the correlation between urban space and cardiovascular health in the context of severe cold climate requires to be understood. Here, the specific impact of urban spatial characteristics on cardiovascular health in winter and the role that urban space can play in resisting the threat to cardiovascular health posed by severe cold climate need to be further clarified.

2. Significance and theoretical framework construction of urban space planning regulation research based on cardiovascular health in severe cold regions

2.1. Research significance

Focusing on specific diseases to improve the quality of urban space planning, the research of urban space planning regulation help to promote healthy city planning in severe cold regions for reducing the risk of cardiovascular diseases. As for the severe cold cities in China with more harsh winter weather, more aging population and more higher risk of cardiovascular diseases, the research has more special significance. Taking Heilongjiang Province (a typical province located in severe cold regions) in China as an example, clinical data shows that hypertension, heart failure, coronary heart disease, arrhythmia and thrombotic diseases caused by severe cold climate are quite common in the province. Among the diseases, the prevalence of hypertension is 25.69% in the province, while that of the nation is only 18.81% averagely. Research from Harbin, a typical severe cold city in China, shows that cold temperature is responsible for 2.7 percent of deaths, especially for coronary heart disease patients who are affected by cold stimulation most (Liu Z. X., 2013). At the same time, Harbin has entered a fast development period of population aging. At the end of 2016, there were 1.924 million elderly people, accounting for 20 percent of the total population in the city (the 13th Five-Year Plan for the Development of Harbin Aging Cause, 2017). With significant high-risk population gathering characteristics, the city is facing a very serious situation of cardiovascular diseases. Therefore, it is of great significance to explore how to carry out urban planning for promoting cardiovascular health in the context of severe cold climate to improve relevant theoretical research and practical development in the field of healthy urban planning as well as healthy aging.

2.2. Theoretical framework construction

Based on the analysis of the relationship between severe cold climate, urban space and cardiovascular health as well as the illustration of the research significance, we intend to establish a theoretical framework of urban space planning regulation research based on cardiovascular health in severe cold regions. We aim at adding the content of urban space planning regulation research focusing on specific diseases- cardiovascular diseases in the context of regional climate to the existing research on healthy urban planning, with emphasis on the potential impact of urban space in severe cold regions on cardiovascular health, thus to enable the urban space to play a role in reducing the cardiovascular disease risk and promote cardiovascular disease rehabilitation to a certain extent.

The theoretical framework, shown in Figure 1, illustrates two pathways of urban space planning regulation research based on cardiovascular health in the context of severe cold climate. The first pathway in the framework is achieved by the protection of urban space for cardiovascular health, namely through urban space planning and design, to reduce the damage resulting from the adverse environmental problems on cardiovascular health, including reduction of cardiovascular disease risk from the low temperature, temperature change between indoor and outdoor space and air pollution. The second pathway in the framework is achieved by the active intervention of urban space for cardiovascular health, namely through urban space planning and design, to promote the occurrence of overall daily physical activities and exercise beneficial to cardiovascular disease prevention and rehabilitation.

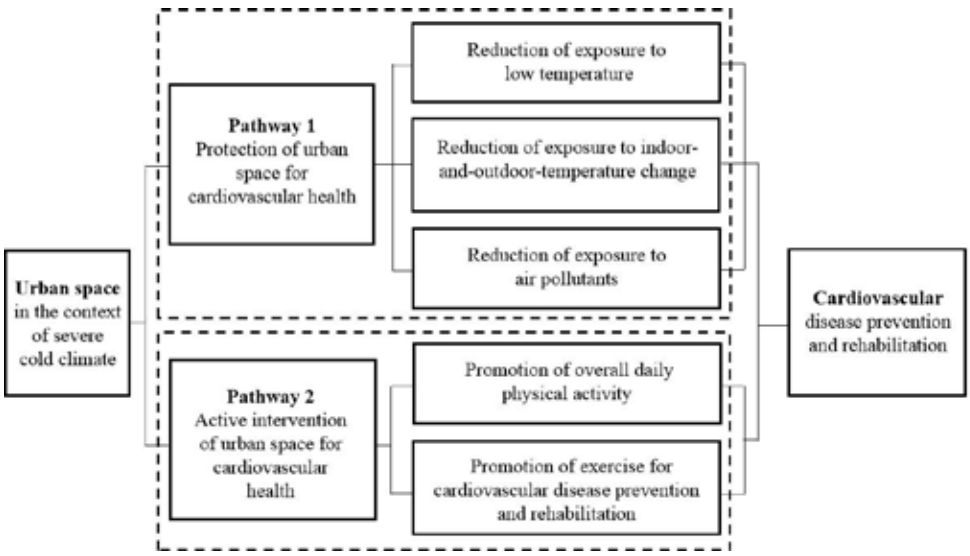

Figure 1 Theoretical framework of urban space planning regulation research based on cardiovascular health in the context of severe cold climate

In combination with these two pathways, the analysis of the situation and planning regulation in the urban space planning regulation research based on cardiovascular health in severe cold regions can be done from two perspectives. From the perspective of the protection of urban space for cardiovascular health, the research should emphases on cardiovascular disease risk factor analysis, including the content of exposure analysis of low temperature environment, indoor-and-outdoor-space temperature change and air pollution. By identifying regions and nodes where cardiovascular health is faced with greater climate impact and the disease risk is higher, key regulatory areas will be determined, and then

corresponding planning regulation can be carried out. From the perspective of the active intervention of urban space for cardiovascular health, the research should emphases on the analysis of supportive elements of overall daily physical activities and exercise beneficial to cardiovascular disease prevention and rehabilitation, including the content of daily public service facilities and public space. By analyzing the correlation between supportive factors and the promotion of physical activity for cardiovascular disease prevention and rehabilitation, the regulatory objectives of public facilities and public space will be determined, and the corresponding planning regulation can be carried out.

3. Urban space planning regulation based on cardiovascular health in severe cold regions

3.1. Cardiovascular disease risk factors analysis and planning regulation

There may exist risk factors with potentially negative effects on cardiovascular diseases in severe cold regions. We suggest to analyse and clarify the potential types and spatial distribution of pathogenic risk factors in planning schemes or projects, and then carry out targeted planning regulation on this basis. It can be carried out from the low-temperature exposure, indoor-and-outdoor-temperature change exposure, air pollutants exposure and other factors that have influence on cardiovascular health.

Reducing the low temperature exposure level of residents in urban space is conducive to improving the safety and comfort of urban space, so as to mitigate the severe impact of low temperature environment on human cardiovascular system properly. Low-temperature exposure is distributed in various places of residents' outdoor where people participate in travel, leisure, exercise, entertainment and other daily activities. Given the restriction of natural meteorological conditions, the low-temperature environment of these places is difficult to be changed significantly. Therefore, it is advisable to focus on key areas for regulation, especially where winter activities are particularly threatened by low temperature, such as traffic waiting area, leisure and exercise-oriented public space and so on. First of all, the waiting node can be designed to defend the climate. For example, the heated waiting hall, connecting corridor, underground passage, overpass bridge and gray space of eaves corridor can be set up at the transitional space between traffic and buildings. Secondly, the physical environment of public space can be designed and optimized. For instance, the form of streets and the layout of public space can be optimized and adjusted based on the analysis of sunshine and wind environment. Thirdly, the capacity of indoor activity space in winter can be expanded, such as the sharing of indoor activity space with school or office at different time.

Given the impact of indoor-and-outdoor-temperature change on the intensity of human blood vessel contraction and diastole, the adaptive design of indoor-and-outdoor-temperature difference is favorable to alleviate the human blood circulation obstacle resulting from it. The indoor-and-outdoor-temperature change exposure mainly exists in the boarder area between indoor and outdoor space, such as the area between the indoor space of residential houses, daily activity facilities and outdoor public space. The variation of temperature difference between indoor and outdoor space mainly exists in the area between the indoor space of residential houses, daily activity facilities and outdoor public space. In the process of planning regulation, combining medical research and methods of the temperature test and simulation of the boarder area, the thermal comfort survey and so on, indoor-and-outdoor-temperature range for reducing the degree of vascular contraction diastole can be confirmed. With regards to planning regulation strategies, the temperature environment of outdoor entry space,

the temperature gradient design of transition space, and the temperature design of the indoor space can be considered, achieving the gradual buffer and transition of indoor-and-outdoor temperature.

Air pollutant exposure is another important factor that causes cardiovascular diseases. Analyzing the types and spatial distribution of air pollutant exposure and proposing targeted planning regulation strategies are helpful to reduce the concentration of pollutants and thus to weaken their harm to the human cardiovascular system. The main types of air pollutants that affect cardiovascular health include haze and automobile exhaust. The exposure of pollutants is mainly distributed in the travel path, road intersection, traffic transfer waiting area, and the adjacent area between the activity area and the road among the daily activity space of residents. With regards to planning regulation, methods such as layout adjustment, shape optimization and pollution source isolation can be adopted to reduce the exposure of air pollutants. The specific ways include adjusting the pollution source land, optimizing the block form, setting up the greening-isolation belt of fitness ground and configuring the dust plants.

3.2. Cardiovascular disease prevention and rehabilitation resources analysis and planning regulation

Combined with the concept of health resources proposed by Wang Lan et al (Wang L. *et al*, 2018), from the perspective of active intervention of urban space for cardiovascular health, the supporting factors of the urban space for physical activity for cardiovascular disease prevention and rehabilitation will be analyzed here. Taking the promotion of overall daily physical activity as well as exercise for cardiovascular disease prevention and rehabilitation as two goals, we propose three aspects involving analysis and planning regulation, consisting of accessibility and proximity of daily public service facilities and public space, convenience and connectivity of facilities combination, the support of physical fitness facilities for cardiovascular disease prevention and rehabilitation.

The accessibility and proximity of daily public service facilities and public space is an important precondition to attract residents to the facilities and space for physical activity, which plays an important role for people to develop daily exercise habits and form exercise compliance-both for the healthy people and patients with confirmed cardiovascular diseases and those with potential risk of cardiovascular diseases such as diabetes, hypertension and hyperlipidemia etc. The accessibility and proximity can be analyzed by GIS to identify the overall fairness of the planning area and the supply and demand matching, on the basis of the distribution of the elder or patient population. Then planning regulation can be implemented focusing on the areas with higher risk of cardiovascular diseases, with regulatory elements such as road network structure, pedestrian space, barrier-free facilities, site layout and so on (Zheng C. Y. *et al*, 2017).

The convenience and connectivity of facility combination play a role in cardiovascular disease prevention and rehabilitation mainly through residents' daily use of facilities to promote traffic walking physical activities, so that residents can improve their physical activity level to some extent even if without deliberate exercise. Taking an old man suffering from cardiovascular disease as an example, the combination and connectivity optimization of facilities such as the market and the physical fitness facilities with high frequency of daily use can provide convenient walking travel options for him, so that he can complete daily travel more on foot. In addition, enhancing convenience and connectivity of facility combination can also help reduce prolonged low-

temperature exposure in winter, with dual protective and intervention effects for the prevention and rehabilitation of cardiovascular diseases. The analysis of convenience and connectivity of facility combination can be carried out through questionnaire, interview and other survey methods to investigate residents' and patients' use frequency and demand for daily public service facilities and different facilities combination, and to combine or set up facilities with high use frequency and demand nearby (Li M. *et al*, 2017). Apart from that, the spatial environment of the connection path of facilities can be investigated and analyzed through field survey and other methods, and also the targeted regulation strategies can be brought forward, such as adjusting the connection path of facilities used frequently and connecting the interruption path, so as to enhance the connectivity of the path.

The support of physical fitness facilities for cardiovascular disease prevention and rehabilitation means to analyze and planning regulate the physical fitness facilities according to medical research and exercise prescription for cardiovascular disease prevention and rehabilitation. Medical research indicates that exercise is essential for cardiovascular disease prevention and treatment, which should be regarded as significant as diet control (Chinese Guidelines for the Prevention and Treatment of Type 2 Diabetes, 2018; Joshua J. J. *et al*, 2019). The contents of exercise prescription for the prevention and rehabilitation of cardiovascular diseases include exercise items, intensity, time and frequency. In terms of exercise items, according to the research from Lancet, the top three exercises that are most beneficial to cardiovascular health are swinging, swimming and aerobics (Lee I. *et al*, 2012). In addition, as a safe, simple and easy exercise to adhere to , walking is considered as the first choice of exercise for elderly diabetic patients. Then the demand of walking and aerobics for physical fitness facilities in winter can be analyzed, such as the layout and design of anti-skid track in the community, as well as the composite use with the residents of lower age groups. In terms of exercise intensity, middle-aged and elderly patients should take low-intensity exercise due to more complications, while young people or individuals with better physical quality can take shorter and higher intensity or interval training (at least 75 minutes/week). Then the preference features of medium and low intensity exercises for physical fitness facilities can be analyzed, such as the site size, facility preferences, so as to adjust the site design and facilities configuration. In terms of time and frequency, for most people, the general recommendation is to exercise at least five days a week for at least 30 minutes a day, or 150 minutes a week. Then the thermal comfort environment of physical fitness facilities in the ideal time of exercise in winter can be tested and simulated to obtain the differences of the thermal comfort status of different positions in the public spaces. Based on that, the site selection and layout adjustment for different exercise prescription items can be carried out to extend the exercise time. The environmental factors that attract residents to stay can also be investigated and analyzed, such as winter ice sculpture, snow sculpture, and night lighting, so as to set up corresponding spots to enhance sports frequency and cultivate sports compliance by enhancing the attraction of physical fitness facilities.

4. Conclusion

With the comprehensive analysis of the relationship between the severe cold region, urban space and cardiovascular health, this paper introduces the significance of urban space planning regulation research based on cardiovascular health in severe cold regions. Then a theoretical framework is established, illustrated as two pathways, one path is to reduce the pathogenic risk factors in the urban space, the other is to promote the physical activities for cardiovascular disease prevention and

rehabilitation. In addition, we propose corresponding planning regulation strategies on the basis of pathway analysis. This paper has made a preliminary discussion in theory, in order to provide a basis for subsequent empirical research, and to provide new ideas and methods for healthy urban planning for reducing the risk of cardiovascular diseases in the context of severe cold climate.

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