Urban green spaces can not only offer a wide range of ecosystem services, but also promote public health. Most of existing studies have effectually explored the correlation between urban green spaces and public health, but failed to dig the complex impact mechanism behind. This article firstly goes into the positive and negative impacts of urban green spaces on public health, and proposes a theoretical framework of the impact mechanism from perspectives of physical activity encouragement, stress management, social cohesion enhancement, and regulating / supporting services provision by ecosystems. On this basis, 6 health-oriented urban green space system planning strategies are proposed, including promoting the availability, improving the accessibility, enhancing the visibility, optimizing the spatial composition, constructing a network pattern of urban green spaces, and reducing the negative impacts of urban green spaces on public health. The research results can provide theoretical grounding and reference for public health promotion and sustainable urban development to exert more health benefits with limited urban green spaces.

KEYWORDS
Public Health; Urban Green Spaces; Nature-Based Solutions; Ecosystem Services; Urban Green Space System Planning
1 Introduction

The rapid urbanization has caused people to migrate from rural to urban areas, where have become the primary habitat for human beings. In the meantime, the living environments and health status of people are heavily challenged. For instance, mental disorders and chronic diseases are prone to happen either due to fast pace of living, increasing competitive pressure, sedentary lifestyles without physical activity, or the shrinking of green spaces\textsuperscript{[1]}~\textsuperscript{[3]}. Under such circumstances, “Nature-Based Solutions” (NBS), aiming at using natural resources to effectively and adaptively address a range of environmental challenges while bringing economic, social, and environmental benefits, have become a key course of action\textsuperscript{[4]}. With its innovative response, NBS emphasizes the theoretical value via design practices to achieve urban resilience, harmonious human-nature relationship, and sustainable resource utilization\textsuperscript{[5]}. In this regard, urban green spaces could act as a crucial NBS because it provides not only extensive ecosystem services\textsuperscript{[6]}, but also opportunities for people to get close to and enjoy the nature with benefits such as stress relief and health improvement\textsuperscript{[7]}~\textsuperscript{[9]}. Specifically, Maja Vujcic et al.\textsuperscript{[10]} found that NBS can effectively relieve participants’ feelings of stress, depression, and anxiety in an interdisciplinary research on the linkage between urban natural environments and human psychological health. Matilda van den Bosch et al.\textsuperscript{[11]} further introduced an NBS framework to summarize positive effects of urban natural environments on public health. However, such studies on how urban green spaces may impact public health and human well-being are insufficient as most of the current NBS-related research focus mainly on mitigating ecological and environmental problems. Moreover, although considerable studies have explored the links between urban green spaces and public health, there is still a gap in identifying and structuring their complex mechanism of action\textsuperscript{[12]}~\textsuperscript{[14]}, which directly impedes the implementation of relevant strategies in urban green space system planning and design\textsuperscript{[15]}. In response, this study explores the positive and negative impacts of urban green spaces on public health, constructs a theoretical framework for the mechanism of urban green spaces in promoting public health, and finally proposes potential strategies and inspirations for health-oriented urban green space system planning to realize the value of NBS.

2 Impacts of Urban Green Spaces on Public Health

The Constitution of the World Health Organization defines that health is a state of complete physical, mental, and social
well-being and not merely the absence of disease or infirmity\textsuperscript{[16]}, according to which it may cover physical health, mental health, and social health. A large collection of papers have studied the link between urban green spaces and public health via experimental research, case study, and longitudinal research.

Regarding the physical health, urban green spaces are proved effective in reducing people’s risks of suffering from chronic and clinical diseases, thus lowering the mortality rate. For example, Mireia Gascon et al. systematically reviewed 12 papers and found that the mortality rate is relatively lower in residential areas with higher greenery coverage—especially for mortality caused by cardiovascular diseases\textsuperscript{[17]}. Studies have also indicated a close relation between urban green spaces and the incidence of clinical diseases such as heart disease, respiratory diseases, liver cancer, and chronic hepatitis B\textsuperscript{[11]}. Furthermore, urban green spaces can help decrease the morbidity of metabolic diseases, such as obesity and diabetes\textsuperscript{[18]}. The area (or accessibility) of surrounding green spaces is closely associated to residents' mental health. Recent reviews have pointed out that some mental illnesses, such as anxiety disorder\textsuperscript{[19]}, attention deficit hyperactivity disorder (ADHD)\textsuperscript{[20]}, schizophrenia, and depression\textsuperscript{[21]}, can be ameliorated with urban green spaces. Additionally, a large amount of research with experimental data and self-reports showed that experience and physical activities in green spaces may catalyze positive moods. These studies were normally conducted on the basis of two main theories, i.e. the Stress Reduction Theory proposed by Roger Ulrich\textsuperscript{[22]} and the Attention Restoration Theory by Stephen Kaplan\textsuperscript{[23]}, and developed by the investigations of single as well as cumulative occasions of nature contact. Relevant research confirmed that urban green spaces improve not only the positive moods and happiness of the public\textsuperscript{[24]}, but also children’s memory and attention\textsuperscript{[25]}, cognitive functioning\textsuperscript{[26]}, learning behavior\textsuperscript{[27]}, imagination, and creativity\textsuperscript{[28]}. On the level of social health, urban green spaces provide opportunities for residents to interact, which enhances their sense of coherence, support, and participation\textsuperscript{[29]} with a better understanding of the worthwhile or good life\textsuperscript{[30]}. In the meantime, place attachment\textsuperscript{[31]} would also come into being with increased social cohesion and social capital, and finally the social health.

However, studies have shown that urban green spaces may also have negative impacts on public health: 1) pollen allergy caused by pollen emission\textsuperscript{[32]}; 2) the spread of infectious diseases (such as malaria) accelerated by mosquitoes flying in urban green spaces (especially around water bodies)\textsuperscript{[33]}; and 3) injuries caused by urban green spaces management activities\textsuperscript{[34]}.
3 Impact Mechanism of Urban Green Spaces in Promoting Public Health

3.1 Exposure of Urban Green Spaces and Public Health

In realizing the health promotion benefits, urban green spaces should be able to have full “exposure” to residents. “Exposure,” as a broad term, here means the exposure degree of urban green spaces based on their natural features (size, type, and qualities such as configuration), which is often assessed by various indicators including the availability, accessibility, and visibility. Availability refers to the total area or proportion of the green spaces, or the average NDVI within a defined spatial distance. Accessibility is the distance or time spent from residence to parks, which can be estimated by the Euclidean Distance or network distance by ArcGIS or travel times via API data from digital maps. Visibility represents the green spaces that can be seen visually when residents commute or move around the residential communities, which are usually accessed from self-reports or Google Earth Street View.

The selection of different “exposure” indicators, to a certain extent, depends on the mechanism of urban green spaces impacting public health. For example, when emphasizing the ecosystem services provided by urban green spaces, especially the health benefits as regulating services, the indicator of availability is preferable; accessibility is usually used to assess the health benefits associated with human activities—such as promoting physical activity; visuality is more applicable in evaluating the effect of urban green spaces on mental health—especially concerning questions based on Attention Restoration Theory and Stress Reduction Theory (Fig. 1).

3.2 Theoretical Framework Construction of the Impact Mechanism

In this study, the impact mechanism of urban green spaces in promoting public health was summarized to 4 approaches: 1) physical activity encouragement; 2) stress management; 3) social cohesion enhancement; and 4) ecosystem regulating / supporting services provision (Fig. 2).

3.2.1 Physical Activity Encouragement

Easily accessible urban green spaces with certain recreational facilities is significant to human physical and mental health, as it could encourage residents to carry out physical activities such as walking and jogging. For citizens, physical activities are usually realized via commuting (walking or cycling) and recreation (sports or touring). For example, Eva Heinen et al. pointed out that people prefer walking or cycling in parks with beautiful and greenery-covered scenes. Studies also confirmed that physical activities in green spaces bring about more health benefits than activities...
城市绿地对人群健康的影响

The impact of urban green spaces on public health

- **鼓励体力活动**
  - Physical activity encouragement
  - Fitness exercises
  - Walking / cycling

- **缓解精神压力**
  - Stress management
  - Sleep quality improvement
  - Stress reduction
  - Attention restoration

- **促进社会凝聚力**
  - Social cohesion enhancement
  - Communication space provision
  - Social activity facility provision

- **生态系统调节服务**
  - Ecosystem regulating services
  - Air purification
  - Water purification
  - Noise reduction
  - Rainwater and flood regulation
  - Urban heat island effect mitigation

- **生态系统支持服务**
  - Ecosystem supporting services
  - Microbial diversity

- **降低慢性病风险**
  - Risk reduction of chronic diseases
    - Skeletal diseases
    - Cervical spondylosis

- **降低代谢性疾病风险**
  - Risk reduction of metabolic diseases
    - Obesity
    - Diabetes

- **降低精神疾病风险**
  - Risk reduction of mental diseases
    - Depressive disorder
    - Anxiety disorder

- **降低临床疾病风险**
  - Risk reduction of clinical diseases
    - Cardiovascular diseases
    - Gastrointestinal diseases
    - Respiratory diseases
    - Heatstroke

- **降低中暑等热病风险**
  - Risk reduction of heat-related diseases

- **增强免疫系统**
  - Immune system enhancement

- **提升幸福感**
  - Well-being improvement
  - Happiness
  - Positive mood

- **缓解精神压力**
  - Stress management

- **生理健康**
  - Physical health

- **心理健康**
  - Mental health

- **社会健康**
  - Social health

- **生态健康**
  - Eco-health

- **提高城市绿地可达性**
  - Improve the accessibility to urban green spaces

- **提高城市绿地可获得性**
  - Improve the availability of urban green spaces

- **增强城市绿地可视性**
  - Enhance the visibility of urban green spaces

- **优化城市绿地空间布局**
  - Construct a network pattern of urban green spaces

- **健康导向的城市绿地系统规划**
  - Health-oriented urban green space system planning

- **降低城市绿地对人群健康的消极影响**
  - Reduce the negative impacts of urban green spaces on public health
happened in other (such as indoor) environments. Moreover, along with physical activities, risks of chronic and metabolic diseases, e.g., cardiovascular diseases known as the “No. 1 killer worldwide,” could be decreased.

3.2.2 Stress Management

For the public, more positive emotions with less fatigue and stress will generate after urban green spaces experience or outdoor physical activities. Empirical evidence showed that people living adjacent to green spaces are much more emotionally resilient with less mental stress and better attention focusing. With self-reports by participants and analytical analysis of the correlation between each indicator of exposure and health, a great deal of research proved that experience or activities in green spaces could help improve sleep quality and relieve stress, which are two main causes of mental illness, especially depression. The study of Gregory N. Bratman et al. suggested that the activation of anterior cingulate cortex, dorsolateral prefrontal cortex, and dorsomedial prefrontal cortex increased after the interaction between human and nature, thereby enhancing people’s resistance to mental illness.

3.2.3 Social Cohesion Enhancement

Social relations can be affected by social relations through the avenues of social participation, support, influence, and interaction (bond). Urban green spaces (especially community parks) can provide public spaces for people to constantly interact with neighbors, during which process their sense of participation, self-identity, and happiness will be enhanced. For example, a case study in East London showed that social interaction happened in urban green spaces catalyzed relationship building between participants and others, while encouraging their sense of community and desire of reorganizing relationships to meet daily needs. Researchers in Chicago have found that public spaces with higher vegetation coverage, such as trees and grass, see more informal social interactions between neighbors.

3.2.4 Ecosystem Regulating / Supporting Services Provision

In recent years, many scholars have put forward the concept of “Eco-health,” and defined it as an exporter of extensive ecosystem services—especially regulating and supporting services—to promote the mental and physical health, i.e., public health. In terms of ecosystem regulating services, urban green spaces can play a key role in reducing people’s pressure from the environment by air and water purification, noise reduction, rainwater and flood regulation, urban heat island effect mitigation, etc. to promote public health to some extent. For instance, studies have evinced that
urban green spaces can reduce the risk of clinical diseases such as gastrointestinal and respiratory diseases through some of the above regulating services. Regarding the ecosystem supporting services, researchers mainly focus on the health benefits brought by the rich microbiome (microbial diversity) in urban green spaces as it can strengthen the immune system of users and reduce allergic diseases.

4 Health-Oriented Urban Green Space System Planning

4.1 Promote the Availability of Urban Green Spaces

The indicator of availability is basic for health-oriented urban green space system planning. Urban planners and policy makers are responsible to set reasonable urban green space assessment indicators at the early stage of urban planning, especially regarding new urban areas, aiming at increasing the interaction between human and nature. Existing indicators, e.g. urban green rate, urban green coverage rate, and the per capita green area of the park, are primarily used to assess the quantity of urban green spaces at city or sub-district scales. Given this condition, future research should refine the mode and scale of urban green spaces assessment, better at the community level, to help accurately identify communities suffering from the potential health problems caused by limited urban green spaces. For built-up areas in a high-rise city with less availability to urban green spaces, studies should focus on examining the threshold relationship between urban green spaces and public health. For example, Gero Coppel et al. found that spatial coverages of urban green spaces of less than 2.5% (within a 250-meter-long buffer around the residence) would negatively impact the self-reported health.

4.2 Improve the Accessibility to Urban Green Spaces

Reasonable accessibility to urban green spaces can encourage citizens to not only contact with the nature more frequently, but also participate in various physical activities that bring about more health benefits. Research suggested that the use frequency of urban green spaces steeply declined once the distance exceeded the interval of 300 – 400 meters for citizens without definite trip plans. Margarita Triguero-Mas et al. found a positive association between natural outdoor environments and mental health indicators within the distance of 300 meters. Regina Grazuleviciene et al. pointed out that the probability of normal blood pressure increased by 9%, and that of high-normal blood pressure by 14% for every 300 meters increase in the distance to urban green spaces. On these findings, urban planners and policy makers should take into consideration the distance threshold of 300 – 400 meters to urban green spaces for citizens.
型绿地难度加大，未来以社区公园和街旁游园为代表的小型绿地将成为提升绿地可达性、改善城市居民健康的关键因素。

4.3 Enhance the Visibility of Urban Green Spaces

Viewing urban green spaces may significantly relieve stress. In view of this, the visual contact in urban green space system planning, including the visual focus of the landscape and the main viewing interface during daily activities of the public, should echo with the surroundings. For instance, outdoor spaces that support intensive activities, e.g. residential areas, offices, and commercial zones, should fully consider the integration and echo with the indoor viewing interface (such as windows) for more visible urban green spaces. Furthermore, urban green spaces may also act as the background of landmarks, e.g. the sightseeing tower, for which its designed form should match up with visual focuses of these landmarks to provide a wider green vision for visitors. Finally, the visibility of urban green spaces could also be realized by increasing vertical greening (introducing climbing plants) on fences and façades of building along sidewalks.

4.4 Optimize the Spatial Composition of Urban Green Spaces

Recent findings also showed that spatial characteristics of urban green spaces may affect public health. Huang Qiuyun et al. examined the impact of grasslands, woodlands, and impervious paved areas with virtual reality, pointing out that grasslands relieve stress more efficiently. Payam Tabrizian et al. assessed the restoration potential of different landscape compositions and configurations through the immersive virtual technology and found that mixed forests, sparse forests and grasslands, and deciduous tree species performed the best, while buildings and impervious paved areas showed negative impacts. Deng Li et al. suggested that landscapes with natural forest morphology and water features may be the best physical and psychological recovery environment. In response, urban planners should figure out the rational configuration of “grey” and “green” spaces—the “grey” ones for physical and social activities and “green” ones to relieve stress.

4.5 Construct a Network Pattern of Urban Green Spaces

A network pattern of urban green spaces and park systems is suggested for urban planning and design. For one thing, “Emerald Necklace”-like network structures can enhance可达性, encouraging outdoor activities; and their linear recreational green spaces (e.g. greenways) connecting various green spaces attract citizens to travel on foot or by bicycle, which means
作为纽带连接各个绿地斑块，能够在最大程度上鼓励居民选择步行、骑行等慢行交通出行方式，从而提升体力活动水平。另一方面，网络状的绿地结构有利于城市生态系统的稳定性[63]，从而促进城市绿地生态系统效能提升，减少中暑等病状的发生。

4.6 降低城市绿地对人群健康的消极影响

健康导向下的实践研究还应密切关注对城市绿地所产生的消极影响的回应，如城市绿地植被传粉所导致的过敏性疾病等。据统计，全球有30%～40%的人口正在遭受过敏性疾病的困扰，其中很大一部分病因即源于植物花粉过敏[64]。因此，城市规划设计中应明确城市树种的选择标准，以控制使用某些会大量传播花粉的物种数量。

5 结论

本文以城市绿地促进人群健康的作用途径为切入点，从鼓励体力活动、缓解精神压力、促进社会凝聚力和提供生态调节/支持服务4个层面构建了理论研究框架，并借此提出健康导向下的城市绿地系统规划应对策略。未来研究在进一步深入探索城市绿地对人群健康影响的潜在途径的同时，还应注重城市绿地的健康实践，提出更多面向提升人群生理、心理和社会健康的设计应对策略。如通过绿地的组成（绿地植被种类、绿地中的水体、活动设施等）与配置（绿地的类型、大小、形状等）对人群健康实施“主动式”干预，让有限的城市绿地发挥更大的健康效益。

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