International Journal of Innovative Research and Scientific Studies, 8(2) 2025, pages: 1986-1998

ISSN: 2617-6548

URL: www.ijirss.com

A conceptual framework of public health transformation to tackle chronic diseases and health challenges in Saudi Arabia

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Abstract

Saudi Arabia struggles with rising non-communicable diseases (NCDs), particularly in urban areas, due to socioeconomic and environmental factors. However, a comprehensive model addressing these issues and intervention strategies remains underexplored in existing literature. This research aims to propose an Urban Health Resilience Model (UHRM) outlining core components, key domains, and investigation and intervention strategies to mitigate the increasing burden of chronic and non-communicable diseases in Saudi Arabian cities. The study also investigates various behavioral aspects and public awareness initiatives that impact healthier living. Research data from 348 urban patients in Saudi Arabia were collected via a structured survey questionnaire to evaluate the impact of socioeconomic and environmental factors on increasing NCDs. Through an extensive literature review and data analysis of chronic disease challenges, this study developed a conceptual framework for urban health resilience. The study proposed an Urban Health Resilience Model, which discussed core phases to enhance urban health through targeted investigation and intervention strategies, policy measures, and healthcare innovations. Findings suggest that public health campaigns and policy initiatives play a crucial role in reducing NCDs and improving quality of life. Strengthening urban health resilience through policy reforms, healthcare innovations, and public awareness programs is essential to reducing the burden of NCDs in Saudi Arabia's metropolitan areas. The proposed framework supports Sustainable Development Goal 3 (SDG 3) by advocating proactive interventions and initiatives to promote good health and well-being. It aims to reduce premature mortality from NCDs through prevention and treatment. Additionally, it recommends measures to strengthen health coverage by ensuring equitable access to quality healthcare services.

Keywords: Health initiatives, Non-communicable diseases, Policy interventions, Saudi public health, Sustainable Development Goal 3 (SDG 3), Urban health resilience.

DOI: 10.53894/ijirss.v8i2.5590
Funding: The authors extend their appreciation to Prince Sattam Bin Abdulaziz University for funding this research work through the project number (PSAU/2024/02/31703).
History: Received: 22 January 2025/**Revised:** 4 March 2025/**Accepted:** 10 March 2025/**Published:** 21 March 2025

Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.
Transparency: The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

The rapid urbanization of Saudi Arabia has brought profound transformations to its social, economic, and environmental landscape. However, these changes have also given rise to significant public health challenges, particularly the growing prevalence of chronic diseases such as diabetes, cardiovascular diseases, respiratory illnesses, and many others. As the nation continues its urban growth trajectory towards Vision 2030, understanding and addressing the multifaceted determinants of these health challenges has become a pressing priority for public health policymakers and urban planners. Chronic diseases now account for a significant portion of illness and mortality in Saudi Arabia, straining healthcare systems and impeding sustainable development. Urban centers, as hubs of population growth and economic activity, are disproportionately affected. Factors such as sedentary lifestyles, dietary shifts, environmental pollution, and inadequate urban planning intensify health risks. While existing research has documented the burden of chronic diseases, there remains a critical gap in understanding how urban-specific factors interact with cultural, socioeconomic, environmental, and healthcare dynamics in Saudi Arabia. This gap limits the ability to design effective, context-sensitive interventions to combat the issue. Current studies often address chronic diseases in isolation, focusing on biomedical aspects or only from an environmental dimension. Few investigations adopt a holistic, integrated perspective that considers the interplay of urban design, healthcare infrastructure, and community behavior. Moreover, there is limited research on how these elements intersect with Saudi Arabia's unique socioeconomic culture and environmental context, particularly in rapidly urbanizing areas. This study seeks to address these gaps by exploring chronic disease determinants in a comprehensive, context-specific manner. This study offers an original contribution by integrating multidisciplinary perspectives to address chronic diseases and health challenges in urban Saudi Arabia. By bridging the gap between urban planning and public health, it proposes innovative solutions that are both sustainable and culturally relevant. The research also emphasizes the importance of resilience, introducing strategies to empower communities and healthcare systems to adapt to the dynamic challenges of urbanization. Additionally, the study advances knowledge on chronic disease prevention in Middle Eastern contexts, contributing to global public health literature.

Through an in-depth examination of existing health policies, healthcare systems, and ongoing educational campaigns, the research highlights critical areas for enhancement and explores innovative strategies to improve health outcomes in urban settings. The research also emphasizes the role of technology in transforming healthcare, including the use of telemedicine, health monitoring apps, and data-driven healthcare solutions to improve accessibility and efficiency. It underscores the necessity for multi-sectoral collaboration among the government, healthcare providers, and the community to address the root causes of chronic diseases, promote early detection, and encourage preventative measures. By providing insights into the successes and challenges of public health transformation in urban Saudi Arabia, this study offers actionable recommendations for achieving better health outcomes and extending healthy life expectancy across the nation. Addressing chronic diseases in Saudi Arabia's urban centers is not only a health imperative but also a critical step toward achieving the nation's Vision 2030 goals. This study's integrated approach and context-specific insights aim to transform public health frameworks, fostering healthy cities capable of supporting the well-being of their inhabitants. Through its contributions, the research seeks to catalyze a shift from reactive healthcare systems to proactive, community-centered health initiatives, laying the foundation for sustainable urban living. Research findings will also inform policymakers, urban planners, and healthcare professionals in Saudi Arabia, providing a roadmap for developing healthier urban environments.

2. Literature Review

Chronic diseases are heavily influenced by socioeconomic and environmental factors, shaping their prevalence and management. Social Determinants of Health (SDOH), including economic status, education, employment, and living conditions, contribute to health disparities and chronic disease burdens [1, 2]. Systemic inequalities exacerbate these conditions through chronic stress, epigenetic modifications, and inflammation, often outweighing healthcare access in determining outcomes [3]. Patients in low-resource settings face worse chronic disease trajectories due to poverty, food insecurity, and limited health literacy [4]. The "One Health" approach underscores the interdependence of environmental, human, and animal health [5]. Saudi Arabia's Vision 2030 aims to enhance healthcare through increased private sector investment, disease prevention, and digital solutions, potentially yielding $15–27 billion in economic benefits [6]. Public health policies emphasize sustainability, reducing emissions, and improving environmental conditions to foster long-term resilience [7, 8].

2.1. Social Factors

2.1.1. Educational Level

Education and health literacy play a crucial role in navigating the healthcare system. Individuals with lower education levels often struggle with medical information, leading to medication errors and higher hospital admissions [9]. Education inversely correlates with NCD prevalence, as higher education appears to be protective against these diseases [10]. Higher educational attainment is linked to better health outcomes through improved literacy, job opportunities, and healthier behaviors. Limited access to quality education restricts career prospects and socioeconomic status, negatively impacting long-term health [11].

2.1.2. Urbanization and Lifestyle Changes

Neighborhoods significantly impact healthcare access, with marginalized communities often lacking adequate facilities and facing transportation barriers that aggravate health disparities [9]. In Saudi Arabia, rapid urbanization has led to lifestyle changes, particularly in cities like Riyadh and Jeddah, where high-calorie and processed food consumption and sedentary behavior contribute to obesity and related chronic diseases [12]. Physical inactivity is a major risk factor for NCDs, with 94.9

percent of adults reporting low physical activity [13]. Studies show that perceived access to recreational facilities mediates the link between actual facilities and physical activity, with urban planning influencing exercise levels [14]. Access to free or low-cost recreational facilities improves physical activity, with individual's 42 percent more likely to meet American Heart Association guidelines [15]. Regional disparities in chronic disease rates in Saudi Arabia show higher rates in [16].

Chronic insomnia affects a significant portion of the adult population, with prevalence rates varying across studies. Research shows that 5.5 percent to 6.7 percent of adults in Europe experience chronic insomnia disorder (CID), while in one study, 23.2 percent of adults were affected, with higher rates in females (25.2 percent) than in males (21.1 percent) [17, 18]. Sleep deprivation is closely linked to various chronic conditions, including cardiovascular diseases (hypertension, myocardial infarction), metabolic disorders (type 2 diabetes, obesity), and mental health issues (depression, anxiety) [19, 20]. It intensifies stress responses and increases arterial pressure, contributing to hypertension and other cardiovascular diseases [21]. Chronic insomnia increases the risk of cardiovascular disease, with a relative risk of 1.31 for those with insomnia [22]. Sleep disturbances like obstructive sleep apnea are linked to increased sympathetic activity and systemic inflammation, further raising the risk of hypertension and cardiovascular conditions [23]. Sleep deprivation also impairs insulin sensitivity, increasing the risk of type 2 diabetes by disrupting glucose metabolism [24, 25]. Short sleep duration is associated with insulin resistance, highlighting the importance of good sleep hygiene for metabolic health [26].

2.1.3. Cultural and Social Norms

Tobacco use significantly contributes to chronic respiratory and cardiovascular diseases in Saudi Arabia, with smoking being a major risk factor for conditions like COLD and CVD. The smoking prevalence is 28.05 percent, with 22.7 percent of men smoking [27]. Second-hand smoke exposure affects 67.3 percent of non-smokers, developing respiratory symptoms [28]. Public health strategies should include tobacco control, excise taxes, health campaigns, and multisectoral collaboration [28]. Additionally, targeted programs, cessation initiatives, and improved access to treatment can reduce tobacco use and chronic disease rates [29, 30].

A scoping review of physical activity (PA) and sedentary behavior (SB) in Saudi Arabia found that 80 percent to 90 percent of younger individuals did not meet the recommended 60 minutes of daily moderate to vigorous PA, with 50 percent to 80 percent engaging in over 2 hours of screen time daily [31]. Among adults, 50 percent to 95 percent reported insufficient physical activity, and 50 percent had more than 5 hours of sedentary behavior daily. Regional differences showed the northern and central regions had the highest inactivity, while the southern region had more active individuals [32].

Social connections impact health by providing access to resources and support for healthy behaviors. Strong networks mitigate socioeconomic disadvantages, while weak connections lead to isolation, increasing mortality and mental health issues. Supportive networks offer emotional, financial, and resource assistance, improving health outcomes [11, 32].

2.1.4. Hereditary and Genetical factors

In Saudi Arabia, consanguineous marriages contribute to high rates of hereditary diseases, particularly autosomal recessive disorders, increasing the prevalence of chronic conditions like diabetes. Lifestyle factors further worsen these conditions [33-36].

2.2. Economic Factors

2.2.1. Income Inequalities

Socioeconomic status (SES) profoundly impacts healthcare access and lifestyle choices, shaping health outcomes across populations. Factors like income, education, and social support influence the ability to access healthcare and maintain healthy behaviors, contributing to health disparities [9, 11, 37, 38]. Higher income correlates with better health outcomes, while low income increases risks of chronic diseases and mental health issues due to limited healthcare access [11]. Financial barriers, inadequate insurance, and high costs further restrict healthcare for low-income groups [9, 39].

2.2.2. Limited Healthcare Access & High Cost

Healthcare access disparities for diabetes and hypertensive patients in Saudi Arabia are influenced by regional variations in infrastructure and socioeconomic factors. Urban areas like Riyadh have better healthcare coverage, while rural regions face challenges like limited access to specialized care and long travel distances, negatively impacting disease management [40, 41]. Geographic disparities highlight that rural resident report fewer unmet healthcare needs, yet service inequities persist [42]. Fragmented care, delayed diagnoses, and inadequate follow-up in rural areas worsen health outcomes [43-45].

2.2.3. Unemployment and Occupational Health Risk

Low-income groups face financial, physical, and psychological barriers, leading to delayed care and worse health outcomes, including increased mistrust of healthcare systems [46]. Employment improves health, while unemployment and job insecurity increase stress, limiting healthcare access and perpetuating a cycle of poor health [11].

2.3. Environment Factors

Saudi Arabia's extreme heat and aridity significantly impact health, particularly diabetes and hypertension, by worsening obesity and physical inactivity [47]. Environmental factors such as walkability, air pollution, and noise levels influence the risk of Type 2 Diabetes Mellitus (T2DM). Higher walkability and green spaces lower the prevalence of T2DM, while noise

and air pollution increase the risk [48]. In Plovdiv, Bulgaria, T2DM was linked to high noise levels (Lden 71-80 dB) [49]. Long-term exposure to traffic noise, along with age, BMI, and alcohol consumption, are key risk factors for T2DM [50].

2.3.1. Air Pollution

Air pollution is a major contributor to noncommunicable diseases, with 9 million deaths linked to environmental pollution, including 4.2 million from ambient air pollution [51]. Vulnerable populations face disproportionate health risks due to pollution and inadequate sanitation Vidal, et al. [5]. Particulate matter (PM2.5 and ultrafine particles) increases the risk of cardiovascular diseases by causing oxidative stress, inflammation, atherosclerosis, and myocardial injury, leading to heart disease, stroke, and arrhythmias Abdul-Rahman, et al. [52].

2.3.2. Urban Design and Infrastructure

In recent years, the developments in urban design and infrastructure in Saudi Arabian cities have evolved rapidly due to modernization and Vision 2030 initiatives. Riyadh, Jeddah, and Dammam have seen significant investments in transportation networks, mixed-use developments, and smart city technologies to enhance livability. On the other hand, urban sprawl and car dependency remain challenges, contributing to congestion and pollution within cities, leaving no open space for recreational facilities, walking, and other physical activities [53]. However, efforts to improve walkability and public spaces, such as the Riyadh Green Program, have just started to aim at enhancing sustainability and quality of life. Hence, research suggests that improved infrastructure, including metro systems, is crucial for reducing environmental impact and promoting urban mobility.

2.3.3. Climate Change and Extreme weather

Extreme heat in desert countries poses significant challenges in managing hypertension and diabetes, increasing dehydration, impairing thermoregulation, and complicating medication adherence [54]. Individuals with these conditions struggle with heat dissipation, elevating cardiovascular risks, and mortality, particularly among vulnerable populations Kadi [55]. High temperatures affect medication adherence by worsening side effects, reducing drug stability, and discouraging consistent use [55, 56]. Additionally, excessive heat limits outdoor activity, leading to sedentary lifestyles that contribute to obesity, insulin resistance, and high blood pressure, further aggravating diabetes and hypertension risks [47].

2.3.4. Lack of Greenery

The lack of greenery in Saudi Arabia contributes to higher risks of chronic diseases, including cardiovascular diseases, obesity, and diabetes. Limited green spaces reduce opportunities for physical activity and increase exposure to air pollution and heat stress, intensifying health issues [39, 48]. Communities with limited access to these resources often experience higher rates of health issues [5]. Urban planning incorporating greenery can mitigate these risks.

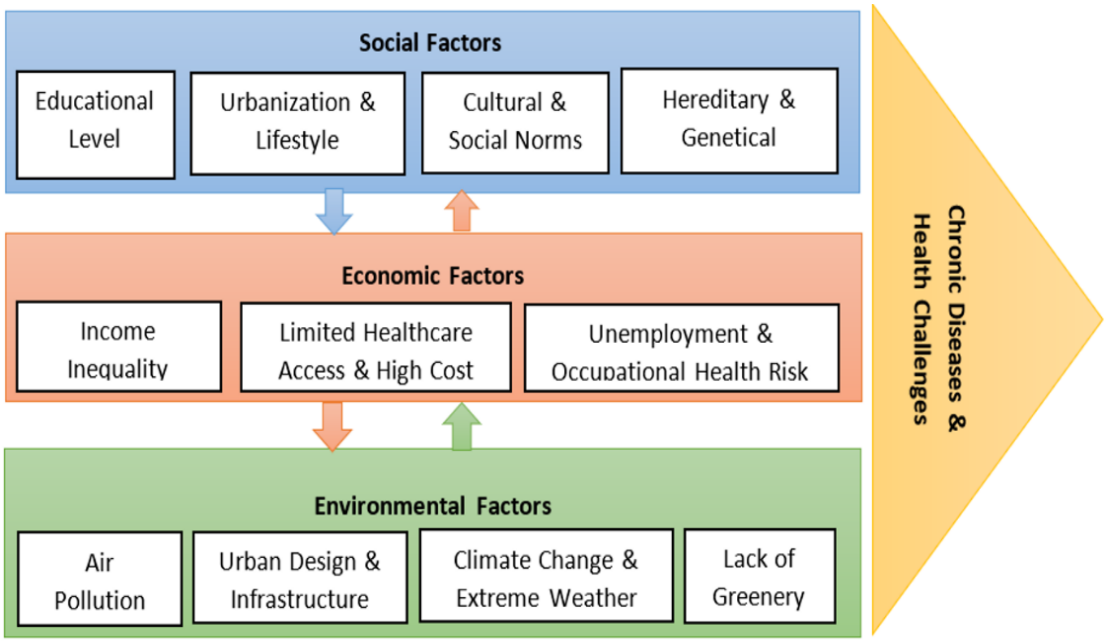

Figure 1.
Interdependent model of socioeconomic and environmental factors towards NCDs.

Global health extends beyond the absence of disease, encompassing physical, mental, and social well-being. Shaped by political, economic, and environmental factors, it demands interdisciplinary strategies and international collaboration to tackle its complex and multidimensional challenges effectively. The interdependent model of socioeconomic and environmental factors causing non-communicable diseases (NCDs) and health challenges is presented as shown in Figure 1.

3. Methodology

The study reviewed existing literature and conducted an in-depth analysis of socioeconomic and environmental factors contributing to chronic diseases. The survey instrument consists of three constructs, namely socio, economic, and environmental. The subfactors and their items were developed based on the repeated dimensions mentioned in the literature review. A structured survey questionnaire was used in a cross-sectional quantitative study, collecting data from 348 chronic disease patients in Riyadh, Dammam, and Jeddah during the period from November 2024 to January 2025. The research aimed to investigate socioeconomic and environmental factors linked to NCDs. Stratified random sampling was employed to ensure proper representation of diverse subgroups, accounting for demographic differences and various types of chronic diseases, thereby ensuring more accurate and reliable results. This paper developed a framework using an in-depth analysis and observation of repetitive frequencies of the items on the scale used in the study.

4. Results

Based on the retrospective literature review and the opinions of the collected data from the respondents identified the below research gaps as shown in Table 1, which are of high priority to address.

Table 1.
Identified research gaps from a literature review.

Author(s) name	Research gap
Conley [4]	Limited focus on targeted interventions in primary care settings to address socioeconomic and environmental disparities affecting chronic disease outcomes.
Emeny, et al. [3]	Lack of integration of structural and systemic determinants in understanding the biological impact of chronic diseases.
Wick [57]	Need for more holistic approaches that address social determinants beyond conventional healthcare interventions
Mercado, et al. [1]	Limited exploration of how social and environmental determinants influence chronic disease outcomes in different populations.
Tucker-Seeley, et al. [2]	Lack of emphasis on policy-driven strategies to address socioeconomic disparities in chronic disease management.
Fisher, et al. [58]	Need for studies linking urban stressors to chronic disease progression.
Al-Hanawi [10]	Limited research on regional variations in NCDs and their association with socioeconomic status.
Venkat Raghav [11]	Lack of research on the intersection between financial limitations and health disparities in chronic disease care.
Al-Khatib [37]	Need for more evidence on how socioeconomic factors directly impact healthcare service utilization.
Tang [9]	Insufficient data on how socioeconomic inequalities shape access to healthcare services.
Al-Zalabani, et al. [32]	Limited research on gender disparities in physical inactivity and their impact on chronic disease development.
Mahmood, et al. [13]	Lack of intervention studies addressing obesity and physical inactivity in Saudi Arabia
Evenson, et al. [31]	Need for better surveillance of physical activity and sedentary behavior trends.
Moreira [54]	Insufficient research on climate-related risks affecting hypertension and diabetes management.
Yu and Song [50]	Limited studies on long-term exposure to traffic noise and its link to type 2 diabetes.
Kattan [40]	Lack of regional analysis on disparities in primary healthcare access.
Alfaqeeh, et al. [41]	Need for comparative studies between urban and rural populations regarding healthcare access.

Also, the demographic data analysis presented in Table 2 revealed that males, comprising 62.07% of the population, exhibit a higher susceptibility to chronic diseases compared to females, particularly within the age group of 46 to 60 years. In terms of educational qualifications, the majority hold either a master's degree (36.78%) or a bachelor's degree (33.33%), and 55.17% are employed. Additionally, a significant portion of the urban population is affected by metabolic and endocrine disorders (24.71%), followed by cardiovascular diseases (14.65%) and cancer (13.22%).

Table 2.
Demographic characteristics of respondents.

Description		Frequency	Percent (%)
1. Gender			
	Male	216	62.07
	Female	132	37.93
2. Age			
	18-30	38	10.92
	31-45	96	27.59
	46-60	164	47.13
	61 and above	50	14.37
3. Education			
	Schooling	44	12.64
	Vocational	32	9.20
	Bachelor	116	33.33
	Master	128	36.78
	Ph.D.	28	8.05
4. Employment Status			
	Student	18	5.17
	Employed	192	55.17
	Unemployed	88	25.29
	Retired	50	14.37
5. Suffering Disease			
	Cardiovascular	51	14.65
	Metabolic & Endocrine	86	24.71
	Respiratory	38	10.92
	Cancer	46	13.22
	Neurological Disorder	24	6.90
	Musculoskeletal Disorder	22	6.32
	Digestive Disorder	21	6.03
	Kidney Disease	19	5.46
	Mental Health Disorder	26	7.47
	Autoimmune Disorder	15	4.31

5. Development of Conceptual Framework of Urban Health Resilience Model (UHRM)

To operationalize this integration, the proposed framework outlines three key phases that connect socioeconomic and environmental aspects. The UHRM provides a structured approach to enhancing public health in Saudi Arabia's metropolitan areas by integrating resilience-building strategies. This model is designed to address chronic health issues such as diabetes, obesity, and cardiovascular diseases through a systems-based and interdisciplinary perspective. Below, Figure 2 presents the detailed conceptual framework of UHRM developed, including core phases, key domains for operational purposes, investigation, and intervention strategies tailored for the Saudi context.

5.1. Core Phases of UHRM

The UHRM is proposed to develop around three interdependent phases: Prevention, Preparedness, and Adaptation.

5.1.1. Prevention

Prevention in the UHRM is about addressing the root causes of health issues before they develop, particularly focusing on mitigating risk factors and encouraging healthier behavioral choices. The key outcomes of the prevention phase are to help lower the impact of health challenges, thereby reducing the overall burden on healthcare systems. It may promote increased awareness and empowerment through education and public campaigns, thereby enabling individuals to become more aware of their health risks and empowering them to make better choices. It provides long-term health benefits by addressing social determinants and fosters long-term health improvements, especially in underserved urban areas where health disparities are most prominent.

Prevention strategies in urban settings often begin with widespread public health campaigns aimed at increasing awareness about health risks. These campaigns focus on both the physical and social determinants of health and may raise awareness about the dangers of smoking, unhealthy diets, lack of physical activity, and environmental hazards such as air pollution. Community-based education, being a key component of prevention, includes schools, healthcare facilities, and local organizations providing the public with the knowledge needed to make informed health decisions. Health education programs cover topics such as nutrition, exercise, mental health, and hygiene. Proactive public health campaigns are in high

need to educate citizens on the prevention, management, and early detection of chronic diseases. These initiatives enhance public awareness and support the identification of health challenges before they escalate, empowering individuals and communities to take action for their own health and well-being. In addition to awareness, behavioral interventions are designed to help individuals adopt healthier behaviors. These interventions may include providing tools and support for people to quit smoking, reduce alcohol consumption, or increase physical activity. Social determinants, such as income, education, housing, and access to healthcare, play a significant role in shaping health outcomes. This creates a supportive environment that addresses these factors, ensuring that all urban residents, regardless of their socioeconomic status, have access to the resources needed to maintain a healthy lifestyle. Prevention efforts are strengthened when urban communities are equipped with resources that enable healthier choices. This includes creating accessible spaces for physical activity (e.g., parks, walking trails), providing affordable healthy food options, and offering health screenings and wellness programs. Community engagement is key to ensuring that these resources are used effectively by residents. Prevention initiatives also thrive through partnerships between local government, healthcare providers, schools, and non-governmental organizations (NGOs).

5.1.2. Preparedness

The Preparedness in UHRM focuses on proactive strategies to improve the resilience of healthcare systems, ensuring they can handle both current and emerging health threats. It emphasizes in development of robust healthcare infrastructure to manage chronic diseases and the ability to identify and respond to health challenges. The below explanation presents its crucial importance in building long-term health resilience to combat the growing burden of chronic diseases.

Health Facilities and Workforce Resources include expanding and modernizing healthcare facilities, including hospitals, clinics, and specialized centers for chronic disease management (e.g., diabetes or cardiovascular care). These facilities need to be adequately equipped with technology, medical supplies, and personnel trained to handle chronic disease cases. Emphasizing training healthcare professionals in chronic disease management, especially in primary care settings, ensures that these workers are equipped with the necessary skills to respond to the complex needs of chronic disease patients. Integrated Care Systems are the integrated care pathways that bring together primary care providers, specialists, mental health services, and social support systems to create comprehensive care for patients, which is necessary for long-term health management. This may include electronic health records (EHR) systems that can track and manage patient histories across different providers. Investments in telemedicine and digital health platforms allow for more efficient monitoring and treatment of chronic diseases, particularly for patients in remote or underserved urban areas.

This infrastructure enables continuous care and regular follow-ups, reducing hospital visits and improving patient outcomes. The creation of sustainable funding mechanisms is imperative, such as insurance systems and government funding, which support long-term chronic disease management programs. Financial infrastructure ensures that both public and private health sectors can provide services consistently. Setting up robust health surveillance systems can track the incidence and prevalence of chronic diseases in urban populations. Early detection of health trends through community health surveys, wearable health monitors, or real-time reporting through digital health systems helps identify at-risk populations and allows health systems to allocate resources where they are needed most. The establishment of rapid response mechanisms and protocols specifically for health challenges, such as disease outbreaks or public health emergencies that worsen chronic conditions, is crucial. The effective allocation of resources and logistics ensures that healthcare services are not overwhelmed during health challenges. Health systems are prepared with contingency plans that involve stockpiling necessary medical supplies, ensuring the availability of medications, and organizing healthcare staff to be on call in case of an emergency. To enhance readiness, healthcare workers and public health professionals are often engaged in simulation exercises to improve their ability to act swiftly and effectively when faced with an urban health challenge.

5.1.3. Adaptation

Adaptation is a critical phase of the UHRM Model that ensures cities can respond to evolving health challenges, environmental changes, and social dynamics. It focuses on long-term sustainability by integrating innovative solutions in technology, policy, and urban planning. Addressing environmental and social vulnerabilities ensures equitable access to healthcare and a healthier, safer urban environment for all residents. Therefore, adaptation strengthens urban health resilience by incorporating cutting-edge solutions that enhance healthcare systems, infrastructure, and governance. Technology integration, such as smart health systems through artificial intelligence (AI)-driven predictive healthcare models, helps detect outbreaks, monitor diseases, and optimize medical resource allocation. Expanding virtual healthcare services improves access to medical consultations, particularly for marginalized populations.

Through Big Data and IoT, real-time health surveillance using wearable devices and environmental sensors helps track air quality, disease patterns, and emergency response needs. Policy reform, such as adaptive policies, ensures urban planning incorporates health considerations, such as air pollution control, green spaces, and active transportation. Regulatory frameworks strengthening healthcare regulations ensure equitable access to essential services and crisis response measures. Governments and private sectors need to work together to improve healthcare delivery, data security, and infrastructure resilience. Expanding parks, pedestrian pathways, and cycling lanes reduces urban stressors and promotes physical and mental well-being. Harris [59] argued that rising temperatures and extreme weather increase heat-related illnesses, cardiovascular stress, and respiratory issues, disproportionately affecting the elderly, children, and vulnerable individuals. Therefore, implementing heat-resistant infrastructure, water-sensitive urban planning, and sustainable energy solutions reduces climate-related health risks. Strengthening regulations on industrial emissions and investing in clean water supply systems improves public health. Promoting urban agriculture and food security initiatives reduces dependency on external

supply chains and ensures access to nutrition. Targeted healthcare programs for low-income communities, migrant workers, and marginalized groups ensure universal access to medical services. Encouraging citizen participation in urban health planning strengthens grassroots resilience and promotes behavioral shifts. Slum rehabilitation, affordable housing projects, and improved waste management enhance overall living conditions.

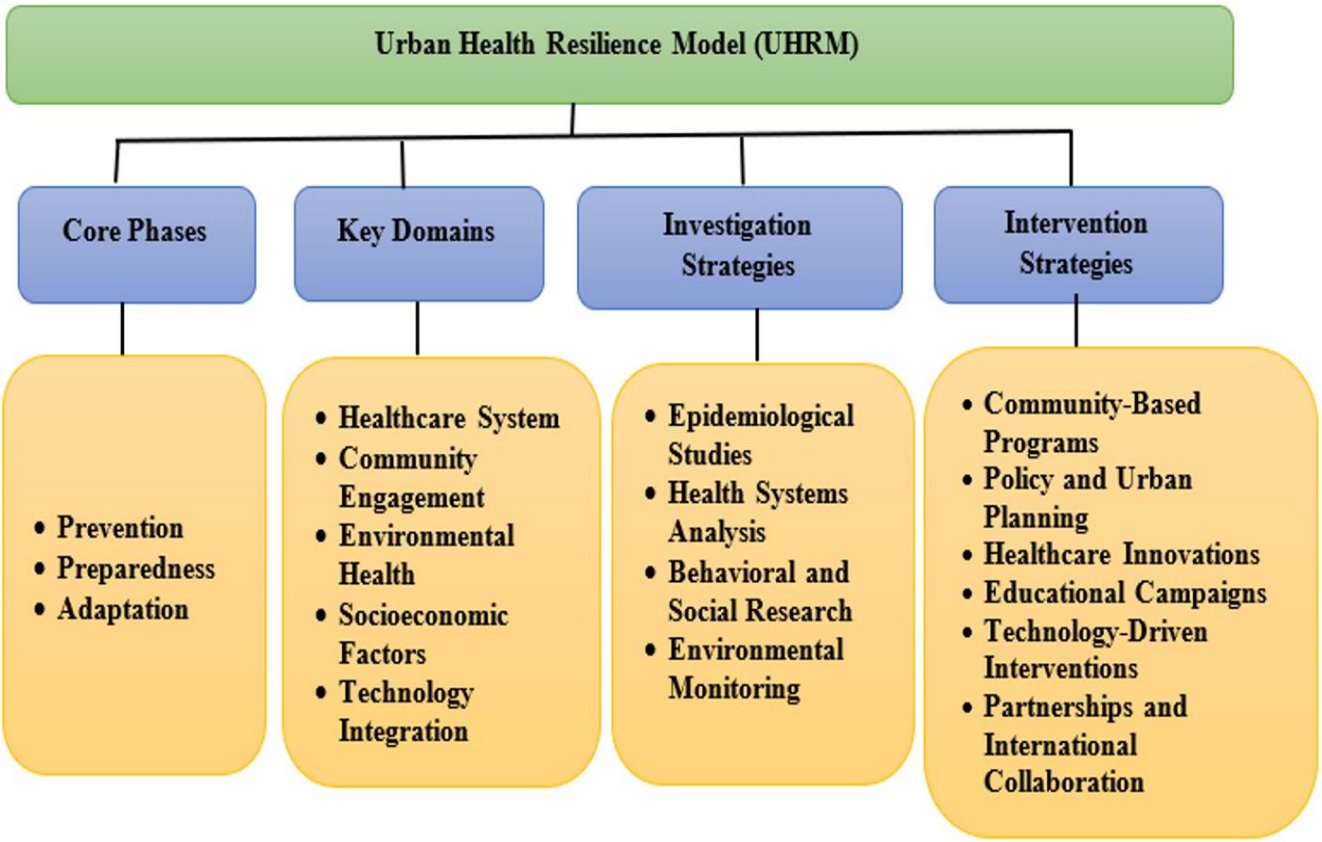

Figure 2.
Conceptual framework of urban health resilience model (UHRM).

5.2. Key Domains for UHRM Operational Plans

The operational framework of UHRM is deliberated to operate across five critical domains to strengthen urban health systems and ensure long-term sustainability.

5.2.1. Healthcare Systems

UHRM enhances capacity, accessibility, and quality of care by improving healthcare infrastructure, expanding medical services, and increasing healthcare workforce capabilities. It emphasizes universal access to primary care, emergency preparedness, and integrated public-private partnerships to ensure equitable healthcare delivery.

5.2.2. Community Engagement

Involving local populations in health initiatives is essential for building resilience. UHRM promotes public awareness campaigns, participatory decision-making, and grassroots health programs to encourage community-driven solutions. By fostering collaboration between residents, healthcare providers, and policymakers, it ensures that interventions are relevant and effective.

5.2.3. Environmental Health

Addressing urban environmental challenges, UHRM focuses on air and water quality management, green infrastructure, and climate-resilient urban planning**.** Measures such as reducing pollution, increasing urban greenery, and ensuring sustainable waste management help create healthier living environments.

5.2.4. Socioeconomic Factors

Recognizing that health is shaped by education, income, and housing disparities**,** UHRM integrates policies to improve affordable housing, job opportunities, and access to quality education**.** These efforts reduce health inequities and promote long-term well-being.

5.2.5. Technology Integration

UHRM leverages digital health tools, telemedicine, and data-driven solutions for disease surveillance, predictive analytics, and remote healthcare services. These innovations enhance healthcare accessibility and enable proactive public health responses, ensuring urban health resilience in the face of emerging challenges.

5.3. Investigation Strategies for UHRM

To operationalize the UHRM, a multidisciplinary approach is needed.

5.3.1. Epidemiological Studies

Research studies noted that lifestyle factors like diet, smoking, exercise, and alcohol use significantly influence preventable chronic diseases, including Alzheimer's and other dementias [60]. Based on this statement, the UHRM conceptual model integrates longitudinal studies to track chronic disease trends in metropolitan populations and use GIS mapping to identify health hotspots and resource disparities.

5.3.2. Health Systems Analysis

A recent study reported a significant rise in chronic conditions among both older and younger populations, attributing this trend to urbanization and sedentary lifestyles. Notably, only 17.4 percent of the Saudi population engaged in the recommended level of physical activity [61]. These combined efforts underscore Saudi Arabia's commitment to transforming its public health landscape and effectively addressing chronic diseases through comprehensive health system analysis and reform. Therefore, UHRM strategies support the assessment of the efficiency of urban healthcare facilities and the investigation of gaps in primary healthcare delivery and referral systems.

5.3.3. Behavioral and Social Research

A recent study on the Chronic Disease Self-Management Program (Stanford model) demonstrated significant improvements in patient self-care and clinical outcomes, including HbA1c and blood pressure levels Asdaq, et al. [62]. Another study in Riyadh found a strong link between chronic diseases, disability, and depression, stressing the need for integrated physical and mental healthcare [63]. Research using the patient assessment of chronic illness care (PACIC) questionnaire identified gaps in non-communicable disease care, urging system improvements [29]. These findings advocate for culturally tailored, patient-centered interventions in Saudi healthcare. Hence the UHRM framework addresses these issues facilitating the study of urban lifestyle patterns

and cultural influences on health behaviors and also explore the impact of socioeconomic disparities on health outcomes.

5.3.4. Environmental Monitoring

Ambient particulate matter (PM2.5) has been identified as a significant health risk in the Kingdom, contributing to 9 percent of total mortality. The persistent pollution underscores the need for robust environmental monitoring and intervention strategies [64]. Additionally, the implementation of electronic infectious disease surveillance systems has enhanced real-time disease detection and response capabilities. Such systems are vital for monitoring health trends and managing outbreaks, thereby strengthening public health infrastructure. Collectively, UHRM efforts highlight the necessity of integrating environmental monitoring with public health initiatives to effectively combat chronic diseases and health challenges in Saudi Arabia.

5.4. Interventions to Improve Public Health

5.4.1. Community-Based Programs

A study in Hafr Al-Batin explored a health education program led by nursing technicians, revealing enhanced health literacy and improved chronic disease management among participants. Another research study assessed the daily practices and learning needs of community health nurses in primary health care centers, emphasizing the necessity for targeted training to bolster public health outcomes [65]. Additionally, the Chronic Disease Self-Management Program (CDSMP) was evaluated, demonstrating its effectiveness in promoting self-care and peer support, aligning with Saudi cultural values. These studies underscore the critical role of culturally tailored, community-driven interventions in enhancing public health and managing chronic diseases within the Kingdom.

5.4.2. Policy and Urban Planning

Studies highlight the need for culturally targeted chronic disease prevention, emphasizing collaboration between researchers and policymakers to develop evidence-based strategies [66]. Additionally, assessments of national policies reveal efforts to strengthen health systems and improve NCD management through comprehensive strategies [29]. So, it is understood there must be robust enforce policies to reduce vehicular emissions and industrial pollutants by developing walkable cities with parks, bike lanes, and recreational areas.

5.4.3. Healthcare Innovations

Under Vision 2030, the Saudi government plans to invest over $65 billion in healthcare, aiming to increase private sector contributions from 40 percent to 65 percent. This initiative includes establishing medical cities and specialized healthcare facilities, as well as enhancing health insurance coverage to improve accessibility and quality of care. Therefore, digital and

other innovations, as mentioned in the UHRM framework, are essential to expand telemedicine services for chronic disease management and integrate wearable technology for real-time health monitoring.

5.4.4. Educational Campaigns

Educational campaigns are pivotal in transforming public health and addressing chronic diseases in Saudi Arabia. A notable collaboration between Qassim University and Stanford University focuses on chronic disease prevention and health promotion. This partnership aims to exchange knowledge and research methods, developing interventions that consider Saudi Arabia's unique social and cultural context [66]. The initiatives of the Saudi Ministry of Health emphasize shifting to and maintaining healthy lifestyles, with a particular focus on diabetes management. The campaigns have achieved success, including increased vaccination rates and recognition such as the "Marketing Pioneers Award" [67]. The UHRM model can address this need and promote awareness of chronic disease and grain healthcare workers to address urban-specific health issues effectively.

5.4.5. Technology-Driven Interventions

Research studies asserted AI transforms medicine by analyzing vast data for predictive modeling, personalized treatment, and population health [59]. Big data aggregates EHRs, genomics, and social factors, enhancing diagnostics in radiology, pathology, and dermatology. Telemedicine improves access, while digital health includes mHealth, wearables, and online education. Hence, technology intervention in UHRM can support in use of big data analytics to predict and manage health risks, also to implement AI-driven diagnostics in primary care.

5.4.6. Partnerships and International Collaboration

Public-private partnerships and philanthropy drive innovation, as seen in Gavi's success in using technology and collaboration to enhance global health [59]. Therefore, it is recommended to have multiple alliances to collaborate with global health organizations to adopt best practices and engage in knowledge exchange programs with urban health experts worldwide.

6. Theoretical and Practical Implications

By incorporating the UHRM to address the issues of chronic disease in Saudi Arabia, this study enhances public health theory. It draws attention to the interrelated roles that adaptation, readiness, and prevention play in managing urban health. The research contributes to resilience-based health models by investigating the impact of socioeconomic determinants, healthcare systems, and environmental elements. It also provides a theoretical framework for long-lasting public health initiatives in urban environments, highlighting the significance of technology, legislative changes, and interdisciplinary cooperation.

In order to improve the treatment of chronic diseases, the study offers practical recommendations for public health professionals, urban planners, and healthcare regulators. To strengthen urban health resilience, it promotes community-based interventions, better healthcare infrastructure, and preventative health campaigns. It encourages technology-driven healthcare solutions by combining data-driven health surveillance, AI-driven diagnostics, and telemedicine. To alleviate health inequities, the research also supports multi-sector collaborations, sustainable urban planning, and legislative changes. These results can guide the execution of comprehensive healthcare plans, ensuring fair access to medical resources and enhancing Saudi Arabia's overall public health outcomes.

7. Limitations

Despite its contributions, this study has several limitations. First, the cross-sectional design restricts the ability to establish causal relationships between lifestyle behaviors and chronic diseases. Second, the reliance on self-reported data may introduce response bias. Third, while the study focuses on major urban centers, it excludes rural populations, limiting generalizability. Additionally, socioeconomic and cultural variations may influence health behaviors in ways not fully captured. Lastly, constraints in longitudinal data and real-time health monitoring hinder comprehensive analysis of disease progression. Future research should incorporate long-term studies and broader demographic inclusion to enhance findings and policy recommendations.

8. Conclusion

This study highlights the urgent need for systematic public health transformation to address the growing burden of chronic diseases in Saudi Arabia. Through the UHRM built on prevention, preparedness, and adaptation, the research underscores the importance of integrated healthcare systems, policy reforms, and community engagement in tackling health challenges. Addressing socioeconomic disparities, environmental risks, and technological advancements is crucial for improving long-term health outcomes. The findings emphasize that proactive prevention strategies, robust healthcare infrastructure, and adaptive urban planning are essential to mitigating the impact of NCDs. Strengthening public-private partnerships and cross-sector collaboration will ensure sustainable health improvements. The rising health risks associated with rapid urbanization in Saudi Arabia can be addressed through this proposed framework, which prioritizes preventive healthcare strategies such as community-based health promotion programs, early disease detection, and lifestyle interventions to enhance overall well-being. Therefore, the proposed UHRM framework plays a crucial role in supporting Sustainable Development Goal 3 (SDG 3) by addressing urban health challenges through proactive interventions. Moreover, it advocates for policy reforms that integrate urban planning with public health strategies, such as expanding access to green spaces and

regulating environmental pollutants. These initiatives collectively aim to reduce premature mortality from NCDs, ensuring that urban populations can achieve healthier and more sustainable living conditions. Furthermore, the framework highlights the importance of strengthening health coverage by ensuring equitable access to quality healthcare services across urban populations, particularly for vulnerable groups. This includes investing in digital health solutions, such as telemedicine and mobile health clinics, to bridge healthcare gaps in underserved communities. Additionally, it suggests enhanced health infrastructure and workforce development to improve service delivery and reduce disparities in healthcare access. The integration of health coverage within urban health policies ensures that all individuals, regardless of socioeconomic status, receive timely and affordable medical care.

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