



# Zip Code Health Disparities: Mapping Cardiovascular Inequities at the Neighborhood Level

REVIEW

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## ABSTRACT

This review examines the multifaceted impact of neighborhood-level social determinants of health (SDOH) on cardiovascular disease (CVD) and outlines strategic interventions for mitigating cardiovascular health inequities. Research highlights that environmental and socioeconomic factors within a neighborhood—including education, unemployment, healthcare access, racial segregation, systemic inequities, air quality, housing quality, and other SDOH—influence CVD outcomes. Addressing CVD disparities necessitates a comprehensive strategy that integrates policy reform, enhanced community infrastructure, improved healthcare access, and community empowerment and leverages innovative technology to create equitable health outcomes across diverse populations.

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## INTRODUCTION

Cardiovascular disease (CVD) remains the leading cause of global mortality and disability,<sup>1</sup> influenced not only by traditional risk factors such as smoking, hypertension, dyslipidemia, and diabetes but also by social determinants of health (SDOH), such as socioeconomic status, education, and healthcare access.<sup>2</sup> Environmental conditions, including air quality, housing quality, and neighborhood safety, are also crucial in shaping health behaviors and CVD risks.<sup>3</sup>

Studies highlight the significant impact of zip codes on cardiovascular health, often exceeding the influence of genetic factors.<sup>4</sup> For instance, individuals moving to zip codes with prevalent uncontrolled health conditions experience corresponding increases in these comorbidities.<sup>5</sup> A Veterans Health Administration cohort analysis showed that relocating to areas with higher rates of uncontrolled health conditions such as hypertension, diabetes, and obesity led to increased incidences of these conditions.<sup>5</sup> Additionally, a study involving more than 27,000 patients found that those in the highest quintile of the Area Deprivation Index (ADI) faced greater readmission risks and mortality after cardiovascular hospitalizations, and including ADI in predictive models notably enhanced risk reclassification.<sup>6</sup> Another investigation of 49,305 refugees resettled in Denmark from 1986 to 1998 revealed that placement in

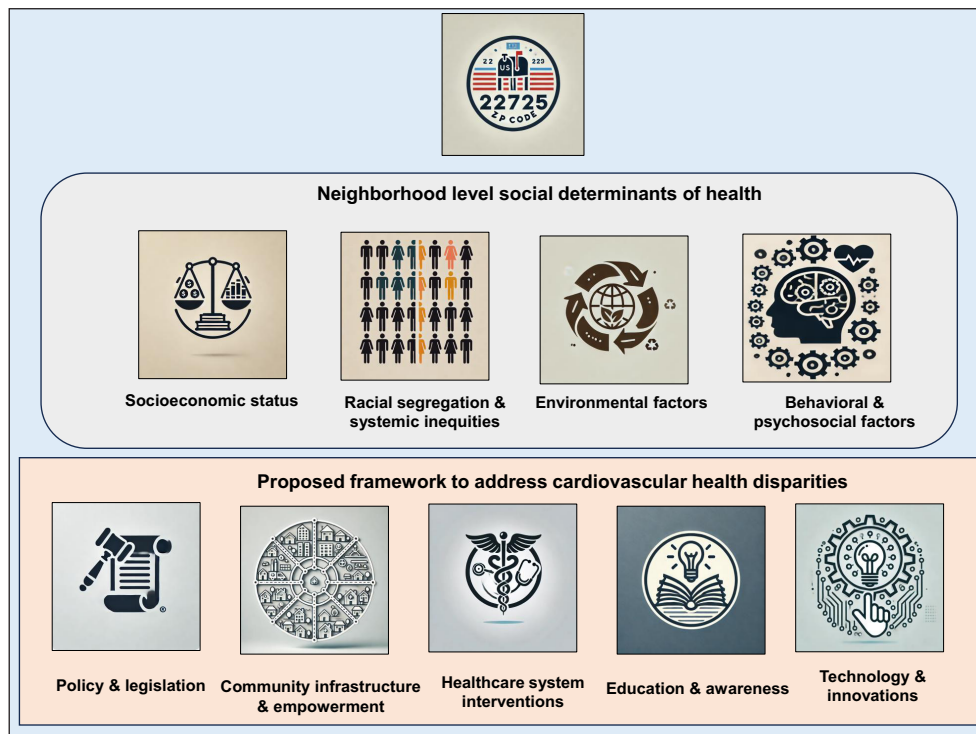
socioeconomically disadvantaged neighborhoods was linked to increased risks of hypertension, hyperlipidemia, diabetes, and myocardial infarction (MI).<sup>7</sup>

Addressing cardiovascular health disparities requires a deep understanding of the complex ways through which neighborhood-level SDOH influence CVD. This review explores the several mechanisms through which zip codes impact cardiovascular health disparities and proposes a multifaceted framework for addressing these inequities. The central illustration provides an overview of various neighborhood-level social determinants impacting cardiovascular health along with proposed strategic interventions to mitigate associated health disparities (Figure 1).

## NEIGHBORHOOD-LEVEL DETERMINANTS OF CARDIOVASCULAR HEALTH

### SOCIOECONOMIC STATUS

A clear inverse relationship exists between neighborhood socioeconomic status (SES) and CVD.<sup>8</sup> While higher socioeconomic levels are associated with decreased CVD risk, residents in lower-income neighborhoods face substantial obstacles, such as limited access to health care, fewer healthy food options, and inadequate recreational facilities.<sup>8-11</sup> A longitudinal study in Israel found a



**Figure 1** Central illustration shows an overview of neighborhood level social determinants of cardiovascular health and potential solutions to mitigate health disparities.

heightened risk of stroke among individuals in lower SES neighborhoods after MI, attributed to community-induced stress and suboptimal care.<sup>12</sup> Another French study observed an inverse relationship between neighborhood deprivation and coronary heart disease (CHD) incidence, only partly explained by traditional CVD risk factors.<sup>13</sup> The residents of US counties with higher socioeconomic deprivation, indicated by the Social Deprivation Index and ADI, were shown to be significantly associated with higher rates of premature CVD mortality.<sup>10</sup> Both indices accounted for a substantial portion of the variation in county CVD mortality, with the most deprived counties showing smaller reductions in premature CVD mortality over the analyzed period. Another study highlighted that young adults ( $\leq 45$  years) in US counties with high socioeconomic vulnerability indices experienced a  $> 10\%$  increase in preventable CVD mortality compared with those in more affluent areas.<sup>14</sup>

### RACIAL SEGREGATION

Neighborhood-level racial segregation significantly increases the risk of CVD, especially within Black communities.<sup>15</sup> Studies have shown that Black adults in segregated areas have a 12% greater risk of developing CVD compared with White adults, a disparity driven by inequities in healthcare access, fewer resources, and historical socioeconomic injustices.<sup>15-17</sup> The National Health and Nutrition Examination Survey (1999-2006) of over 8,000 participants found that Black adults had nearly 3-fold higher odds of hypertension than White adults, but these disparities were notably smaller in areas with low racial segregation.<sup>18</sup> The disparities were pronounced in segregated low-poverty areas and most diminutive in non-segregated high-poverty areas. Another study analyzed diabetes mortality between Black and White populations across the 50 most populous US cities; it showed that Blacks had significantly higher mortality rates in 39 out of 41 cities, ranging from 57% higher in Baltimore to 4-fold higher in Washington, DC.<sup>17</sup> Economic inequality and segregation were correlated with these disparities. Specifically, adjusting for both Black/White poverty and segregation explained 72.6% of the mortality disparity.

### HEALTHCARE ACCESS

Geographic location significantly dictates access to health care, directly influencing cardiovascular outcomes.<sup>3,5</sup> Rural areas often lack specialized cardiac care facilities, imposing delays in treatment that can exacerbate health conditions.<sup>5,19</sup> For instance, the availability and utilization of aortic valve replacement procedures and a scarcity of transcatheter aortic valve replacement (TAVR) programs in rural regions significantly impact mortality rates.<sup>20</sup> A study indicated that individuals in rural counties of Florida

traveled an additional 44 miles to receive TAVR and underwent the procedure at rates approximately seven-times lower than those in more densely populated areas.<sup>21</sup>

Urban residents in poor areas may also face a lack of nearby healthcare facilities and extended wait times, further complicating health management.<sup>9</sup> Research shows a notable variation in challenges accessing medical care across US states, with a median difficulty rate of 13% for the general population.<sup>19</sup> In US states without expanding Medicaid, 1 in 6 residents reported difficulty accessing care.<sup>19</sup> These factors contribute to reduced life expectancy; for example, US rural regions have consistently reported higher age-adjusted mortality rates compared to urban areas, with Black individuals exhibiting higher mortality than other races.<sup>22</sup>

### ENVIRONMENTAL FACTORS

Environment factors such as air quality, housing quality, availability of grocery stores with healthy food choices, the walkability of the area, facilities for physical activities, and the presence of greenspace are linked to achieving optimal cardiovascular health.<sup>3,23</sup> Aided by deep learning, a cross-sectional study analyzed 0.53 million Google Street View images from 789 census tracts across seven US cities to measure the built environment's impact on CHD prevalence.<sup>24</sup> Features from these images, interpreted through convolutional neural networks and activation maps, explained 63% of the variance in CHD rates, enhancing predictions over models based solely on demographic and socioeconomic data.<sup>24</sup> The analysis identified specific neighborhood characteristics, such as buildings and roads, significantly associated with CHD prevalence.

Another study examined 71,659 US Census tracts and found that neighborhoods in the highest quartile for environmental burden had significantly elevated rates of hypertension, diabetes, obesity, CHD, and stroke compared with those in the lowest quartile.<sup>25</sup> The link between environmental burden and cardiovascular health was notably robust in socially vulnerable neighborhoods. On the same note, accelerated urban growth and industrial activities have significantly increased air pollution, posing a critical environmental and health challenge.<sup>26</sup> The 2004 American Heart Association (AHA) scientific statement identified a connection between exposure to particulate matter and cardiovascular incidents.<sup>27</sup> The 2010 AHA update further emphasized the detrimental effects of particulate matter 2.5 ( $PM_{2.5}$ ) on cardiovascular health.<sup>28</sup> Research has demonstrated the association of acute exposure to  $PM_{2.5}$  with MI, stroke, arrhythmias, and heart failure,<sup>29</sup> while prolonged exposure has been shown to reduce life expectancy in populations subjected to high levels of these particles.<sup>30</sup>

## SOCIAL DETERMINANTS

Neighborhood variations in several other SDOH, such as education, employment opportunities, and income levels, critically shape cardiovascular health.<sup>9</sup> Higher educational attainment typically leads to improved health outcomes due to better employment prospects and enhanced access to health care.<sup>9,31</sup> Conversely, lower educational achievements can restrict job opportunities, diminishing economic potential and worsening health outcomes.<sup>9,32</sup> For instance, a study in Australia and New Zealand revealed that individuals with only primary education face higher risks of cardiovascular and all-cause mortality compared to those with tertiary education, with key risk factors being smoking, obesity, and physical inactivity.<sup>8</sup>

Additionally, lower education often results in reduced participation in tertiary prevention programs like cardiac rehabilitation, exacerbating health disparities.<sup>8,31</sup> Another study conducted in the US and Finland identified a persistent increased risk of nonfatal MI and sudden cardiac death among low-income groups, with findings consistent on both individual and neighborhood scales.<sup>11</sup> Another report observed that a \$10,000 rise in a neighborhood's median income corresponded with a 10% decrease in mortality for its residents.<sup>33</sup>

Similarly, research has highlighted the impact of unemployment on cardiovascular health. A French study found that unemployment in the French population led to a 20% increased risk of CHD, with diet and lifestyle factors such as alcohol consumption and smoking explaining nearly half of this risk.<sup>34</sup> Similarly, another US report identified that unemployment was associated with a 35% increased risk of MI in the first year alone, with repeated job losses and extended periods of unemployment compounding this risk.<sup>35</sup>

## SYSTEMIC INEQUITIES

Historical systemic injustices, such as redlining, have perpetuated disparities in housing and neighborhood resources.<sup>4,12,16,36,37</sup> These practices have historically obstructed homeownership among Black adults and relegated them to resource-poor neighborhoods, fostering conditions conducive to higher CVD rates and mortality.<sup>4,36,37</sup> In a US study, veterans residing in historically redlined (grade D) neighborhoods had a 14% higher risk of experiencing cardiovascular events compared with those in lowest-risk (grade A) areas; the risks of MI and all-cause death were increased by 15% and 13%, respectively.<sup>36</sup> Furthermore, socioeconomically disadvantaged neighborhoods, often marked by higher pollution levels, have been linked to a 25% increase in the risk of incident CVD and all-cause mortality in Black versus White populations.<sup>38</sup> Moreover, neighborhoods with over 60% Hispanic residents

experience up to 30% greater exposure to harmful air pollutants such as PM<sub>2.5</sub> than areas with lower than 25% Hispanic populations.<sup>16</sup>

## BEHAVIORAL AND PSYCHOLOGICAL FACTORS

Behavioral and psychosocial risk factors such as smoking, physical inactivity, and unhealthy diets are more prevalent in socioeconomically disadvantaged neighborhoods.<sup>9</sup> Additionally, residents in these areas often experience higher levels of chronic stress and depression, further exacerbating CVD risks.<sup>39</sup> The REGARDS (Reasons for Geographic and Racial Differences in Stroke) study indicated that individuals with an annual income below \$35,000 who experience both stress and depressive symptoms faced an approximately 50% increased risk of developing CVD and a 33% increase in all-cause mortality.<sup>40</sup> Moreover, research shows that these disparities have a pronounced gender aspect. The WISE (Women's Ischemic Syndrome Evaluation) study found that women with CHD and low SES incur higher drug costs and suffer more frequent hospitalizations than their higher-income counterparts.<sup>41</sup> In Southern Alberta's healthcare system, the influence of neighborhood SES on the use of cardiac catheterization and the subsequent 30-day mortality rates post-acute coronary syndrome was noted exclusively among women.<sup>42</sup>

## BLUEPRINT FOR ACHIEVING EQUITABLE CARDIOVASCULAR HEALTH

Addressing neighborhood-level SDOH and mitigating CVD risk requires a multidimensional strategy encompassing policy reform, infrastructure enhancement, healthcare improvements, educational initiatives, and community empowerment. The subsequent sections detail these critical elements, providing a framework for potential interventions to enhance cardiovascular health across diverse communities. This approach emphasizes the need for comprehensive, coordinated efforts tailored to the specific needs and contexts of different communities.

## POLICY AND LEGISLATION

Reforming housing policies to enforce fair housing laws is essential for diminishing racial segregation and promoting inclusive communities.<sup>36,37</sup> Expanding affordable housing initiatives diversifies neighborhood demographics, thereby reducing health disparities.<sup>37</sup> Additionally, enforcing stringent building codes ensures better living conditions, thereby improving health outcomes. Economic revitalization of underserved areas through tax incentives encourages business investment, enhances local employment opportunities, and promotes healthy lifestyles through living wage policies.<sup>8,9,11</sup> Expanding Medicaid coverage

provides essential healthcare access to underserved populations, and increased funding for community health centers enhances primary care services.<sup>19</sup> Implementing stringent air quality standards and regulating industrial pollutants reduce environmental cardiovascular risks,<sup>27,28</sup> while urban planning incorporating green spaces promotes physical activity and mitigates urban heat, contributing to cardiovascular health.<sup>25</sup>

### **COMMUNITY INFRASTRUCTURE**

Enhancing public transportation systems, creating bike lanes, and making streets more pedestrian-friendly significantly improve physical activity.<sup>7,21,25,33,40,41</sup> Similarly, developing parks and recreational facilities in marginalized areas encourages physical activity, while community centers offering fitness programs cater to all ages and abilities, promoting active lifestyles from a young age.<sup>3,11,15,22,25,40,42</sup> Subsidizing transportation costs for low-income residents increases access to health care and healthy food options.<sup>5,19,34,43</sup> Addressing food deserts by incentivizing grocery stores in underserved areas, supporting farmers' markets, and funding community gardens ensures access to nutritious food.<sup>13,33,43</sup>

### **HEALTHCARE SYSTEM INTERVENTIONS**

Increasing the availability of primary care facilities in underserved areas and deploying mobile health clinics and community health workers dramatically improve access to preventative and ongoing care, while establishing satellite clinics for specialized cardiac care reduces travel time for specialized services.<sup>44,45</sup> Telehealth initiatives bridge the gap between rural patients and healthcare providers.<sup>19</sup> Expanding screening programs for CVD risk factors and integrating workplace and school-based health programs facilitate early identification and mitigation of risk factors as well as support with symptom monitoring and medication adherence.<sup>44,45</sup>

### **EDUCATION AND AWARENESS**

Developing culturally and linguistically appropriate health education materials enhances understanding and engagement in health management.<sup>8,9,11,31</sup> Integrating health education into school curricula and community-based health programs empowers individuals to make informed health decisions.<sup>31</sup> Smoking cessation programs, community exercise initiatives, and nutrition education significantly influence lifestyle choices and must be accessible and tailored to meet the community's unique needs.<sup>7,9,31,33,35</sup> Leveraging media and social media for targeted public health campaigns raises awareness and effectively educates the public on cardiovascular health.<sup>46</sup>

### **COMMUNITY EMPOWERMENT**

Supporting the formation of neighborhood health committees and facilitating community-led health assessments empowers residents to identify and act on their health needs.<sup>9,47,48</sup> Participatory budgeting for health initiatives ensures community involvement in allocating local health resources.<sup>47,48</sup> Providing leadership training for community health advocates and developing mentorship programs for youth builds long-term capacity for community health management.<sup>47,48</sup> Establishing support groups for individuals with CVD and at-risk populations provides crucial emotional and practical support, reducing isolation and promoting health-enhancing behaviors.<sup>40,48</sup>

### **TECHNOLOGY AND INNOVATION**

Utilizing advanced technologies such as a geographical information system (GIS) for resource allocation and neighborhood-level health tracking systems optimizes health interventions.<sup>24</sup> Predictive modeling based on SDOH helps anticipate health trends and prepare appropriate responses.<sup>49</sup> Mobile apps for health management, wearable technologies for health monitoring, and AI-powered chatbots for health education transform the approach to cardiovascular health management.<sup>32</sup> Incorporating health considerations into smart city initiatives, such as air quality monitoring and traffic management, enhances urban living conditions and health outcomes.<sup>23</sup>

### **PARTNERSHIPS AND COLLABORATION**

Collaborations across health care, education, housing, and other sectors are crucial for addressing SDOH.<sup>9,48</sup> Public-private partnerships and alliances between academia and community organizations amplify the impact of health interventions.<sup>50,51</sup> Innovative funding strategies like social impact bonds and community development financial institutions focused on health sustain long-term health initiatives.<sup>50,51</sup> Establishing networks for sharing best practices and facilitating collaborations across cities and nations accelerates progress in addressing health disparities.<sup>48,50,51</sup>

## **CONCLUSION**

The profound impact of neighborhood-level SDOH on CVD underscores the need for a holistic approach to mitigate cardiovascular health disparities. While this review has detailed the complex interplay between several neighborhood-level SDOH, effective intervention requires implementing targeted healthcare strategies and broader societal changes that address the root causes of health disparities. By fostering community empowerment, leveraging technology and innovation, and enhancing

infrastructure, we can create healthier environments that enable all individuals, regardless of zip code, to achieve optimal cardiovascular health.

## KEY POINTS

- Neighborhood-level social determinants of health, including socioeconomic status, racial segregation, and environmental factors, significantly impact cardiovascular disease (CVD).
- Disparities in access to health care, influenced by geographic location and community infrastructure, exacerbate cardiovascular health inequities, especially in rural areas and segregated communities.
- Comprehensive interventions that address both individual and neighborhood-level factors are necessary to mitigate CVD disparities effectively.
- Multisector collaborations and the integration of advanced technologies, such as GIS and telehealth, are essential for developing sustainable solutions to reduce cardiovascular health inequities.

## CME CREDIT OPPORTUNITY

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## COMPETING INTERESTS

The author has no competing interests to declare.

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