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Urban sprawl and health: a review of the scientific literature

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Abstract

Urban sprawl is the development of sparse suburban areas with low population density, limited land use diversity, and poor street connectivity. Numerous studies demonstrated that urban form settings influence indoor and outdoor environments and, consequently, public health in diverse ways. This review aims to assess the association between sprawl and each health outcome evaluated in the literature to better define urban sprawl and its effects on human health. Using the PRISMA statement, this narrative review evaluates the associations between urban sprawl and any health outcome analyzed by researchers seeking to assess a possible relationship. A total of 826 records were identified via PubMed/MEDLINE (227) and Scopus (599) and 36 studies were deemed suitable for inclusion: 21/36 studies (58%) focused on obesity as the primary health outcome, 4/36 (11%) on life expectancy and/or mortality, 7/36 (19%) on accidents or emergency medical service response, and 4/36 (11%) on the self-reported psychological distress and/or physical health conditions associated with urban sprawl. In most studies, there is a general lack of uniformity and urban sprawl is loosely defined, with urban sprawl definitions frequently corresponding to different combinations of items within sprawl indexes. Nonetheless, urban sprawl appeared to be a determinant of health in many of the examined outcomes; therefore, it is necessary to promote alternatives to sprawling patterns when developing urban settings.

1. Introduction

Throughout the twentieth century, numerous national governments adopted poorly planned urbanization strategies characterized by the development of sparse suburban settlements with low population density, limited land use diversity, limited street connectivity, and a fragmented and dispersed development, with a propensity toward discontinuity, leaving rural areas [1]. This phenomenon is typically known as 'urban sprawl'. It is historically associated with the post-World War II urban development process in the United States [2], but there is strong evidence of sprawl in Europe [3] and in other parts of the globe. Indeed, according to the Organisation for Economic Co-operation and Development (OECD), urban sprawl has experienced a significant surge in 1156 cities across 29 OECD countries since 1990 [4].

Currently, the era of urban expansion is deemed to be over, necessitating a new approach geared toward urban re-densification and the recovery of underutilized urban areas [5, 6]. On the other hand, the continuous increase in buildable land imposes enormous costs on the community and significantly impacts the quality of the environment.

Various measures of urban sprawl have been hypothesized and established to depict the phenomenon over the years. In addition, its definition has undergone several modifications, making it difficult to locate studies that evaluate the sprawl index using the same geographical and urbanistic patterns.

Each significant system to measure the degree of urban sprawl should be based on a clear and consistent definition of this phenomenon, detaching the urban sprawl itself from the causes and effects that have been progressively identified in different

countries and political systems over the past several decades.

In 2003, Ewing *et al* [7] demonstrated for the first time a correlation between health outcomes, health behaviors, and a 'county sprawl index' that was initially thought to be the result of only two environmental characteristics: development density and street accessibility.

A few years later, scientific advancements on this subject allowed Ewing and Hamidi [8] to expand the number of measures to what is now the most widely used sprawl index. It is characterized by four dimensions: Ewing and Hamidi added land use diversity (or lack thereof) and population and employment centering to the first two detected characteristics (or lack thereof). The second index now assigns the lowest score to counties with classic suburban sprawl patterns [8], whereas the first index previously assigned the lowest score to small towns surrounded by farmland [7]. More recently, the OECD has put forth a proposal to assess the multifaceted nature of urban sprawl by utilizing six distinct indicators that provide a comprehensive understanding of this intricate phenomenon. The six factors under consideration are as follows: (1) the variation in urban population density, (2) the allocation of land-to-density, (3) the allocation of population-to-density, (4) polycentricity, (5) fragmentation, and (6) decentralization [4].

Several studies [9–12] demonstrated that different urban form settings affect the indoor and outdoor environment and, consequently, public health in various ways. The correlation between health outcomes and the built environment has been investigated by a growing number of studies for both public health and planning purposes [13–18], but the specific urban sprawl technical characteristic appears to be undervalued.

However, it has been demonstrated that a sprawling metropolitan area results in lengthy commutes, which decreases leisure time and physical activity. Access to healthy foods may be more difficult in sprawling areas, as it may be more difficult for suburban residents to reach food markets, primary health services, and life-essential facilities [19]. In addition, urban sprawl may diminish community-level social capital by increasing commute times and erecting geographic barriers between regions where people live, work, and shop [20]. Evaluations of urban sprawl should consider density, walkability, proximity, street network connectivity and safety, the presence or absence of community centers, and the mix of jobs, homes, and services in a neighborhood. When examined collectively, these factors may explain why location has a significant impact on health risk [20].

This review aims to assess the association between sprawl and each health outcome evaluated in the literature to better define urban sprawl and its effects on human health.

2. Materials and methods

For the purpose of this narrative review, we analyzed the associations between urban sprawl and any health outcome assessed by researchers who sought to evaluate a potential relationship. The PRISMA statement served as the basis for this review [21]. Scopus and PubMed/MEDLINE were the primary literature sources, and the literature review was first conducted on 2 February 2022, using the following search string:

[urban sprawl AND (health OR mortality OR outcomes OR cardiovascular OR life expectancy OR disease OR obesity OR morbidity OR cancer OR tumor)].

A second record search was conducted on 28 April 2023, after some Reviewers' suggestions. The resulting search string was the following one:

['urban sprawl' AND (health OR mortality OR outcomes OR cardiovascular OR 'life expectancy' OR disease OR obesity OR morbidity OR cancer OR tumor OR mental OR psychological OR accident OR crash)].

Date of publication between 2001 and 2021, English language, presence of a health outcome (life expectancy, mortality, morbidity, obesity, cardiovascular diseases, cancer, etc), availability of a sprawl index, and analysis of the association between sprawl index and health outcome were the inclusion criteria for selected studies.

Only cross-sectional and ecological studies published in English were included, regardless of country of origin. All other study designs, including book chapters, letters to the editor, commentaries, trial studies, prospective cohort studies, before-and-after studies, systematic reviews, narrative reviews, and meta-analyses, were excluded.

A couple of researchers evaluated all the records for the preliminary screening phase. They independently read the articles' titles and abstracts and included them based on the inclusion criteria, to double-check the selected articles. In case of a discrepancy, another external supervisor researcher examined the title and abstract to resolve any doubt.

For the evaluation phase, full-text articles were searched for all eligible records and utilized. During this stage, each pair of researchers independently extracted data from the articles using Microsoft Excel spreadsheets. Another supervisor researcher compared the extracted data and resolved any discrepancies.

The collected variables included the definition of urban sprawl, the study design, the geographic area and the study year, the primary and secondary objectives of the study, the evaluated outcome, and the sprawl index type.

3. Results

3.1. Bibliographic research

As shown in figure 1, a search of the PubMed (227) and Scopus (599) databases yielded 826 records, and 122 duplicate manuscripts were eliminated.

From the 704 remaining records, 544 were excluded after the screening phase: 7% were written in a language other than English ($n = 40$); 31% did not report health outcomes ($n = 166$); 24% lacked both sprawl index data and sprawl definition ($n = 128$); 6% did not involve human beings in their associations ($n = 35$); finally, 32% adopted a different methodology, in particular: 66 articles were commentaries, 55 reports were reviews, 51 were book chapters; moreover, there were two case report studies and one erratum.

During the assessment phase, 159 full-text articles were evaluated for eligibility, and 123 were omitted due to the following criteria: 3% exclusively examined cohorts of solely one gender ($n = 4$), 42% did not report sprawl data or sprawl definition ($n = 51$), and 55% did not report health outcomes ($n = 68$).

In the end, 36 studies were included.

3.2. Characteristics of the included studies

The results are presented in table 1. The 21/36 studies (58%) focused on obesity as the primary health outcome, 4/36 (11%) on life expectancy and/or mortality, 7/36 (19%) on accidents or emergency medical service (EMS) response, and 4/36 (11%) on the self-reported psychological stress and/or physical health conditions associated with urban sprawl.

The 32/36 records (89%) utilized a cross-sectional design, whereas 4/36 articles (11%) opted for an ecological design.

The 23/36 articles (64%) adhered to the definition of urban sprawl coined by Hamidi *et al* [22], 8/36 articles (22%) adhered to the definition given by Lopez [23], and 5/36 records (14%) did not have a clear definition of urban sprawl but used a sprawl index.

As depicted in figure 2, the 26/36 records (72%) assessed health outcomes in relation to urban sprawl in the United States (US), 4/36 (11%) evaluated urban sprawl within the borders of European countries, 3/36 (8%) were conducted in Australia, 2/36 records (6%) examined the Canadian population, and the remaining 1/36 (3%) was conducted in China.

The 11/36 articles (31%) evaluated data collected between 1970 and 2000, while the remaining 24/36 articles (70%) evaluated data collected between 2001 and 2015. One record is missing the years of study [24].

4. Discussion

This review's primary objective was to clarify the relationship between urban sprawl and health outcomes in various geographic regions and their associated populations.

In order to accomplish this, our team analyzed all available cross-sectional studies evaluating the definitions of 'Urban Sprawl' and the impact of this phenomenon on population health worldwide.

4.1. Urban sprawl definition

Sprawl is historically regarded as an American phenomenon due to its dimensions, which are typical of county settings in the United States. In recent decades, global urbanization and rapid population growth have made sprawl an international development concept, despite its unmistakable American origin. Nevertheless, descriptions of urban sprawl lack uniformity because it varies across the globe and through the decades. In Asian and European cities, the so-called low-density development pattern is significantly different from that of American cities.

Currently, the commonly accepted definition of 'urban sprawl' is the extension of a city and its suburbs into the rural areas that border the urban area in question. This process has as its primary outcome the urban dispersion or the scattering of buildings, streets, and shopping centers in continuity with the cities that generated them [25]. Therefore, a sprawling environment is characterized by the following four characteristics: (1) a population dispersed in a low-density residential development; (2) rigidly separated homes, shops, and workplaces; (3) a lack of well-defined activity centers; and (4) poor street connectivity. This definition of sprawl was first articulated by Hamidi *et al* [22]. The majority of included articles (23/36, 64%) met this definition, as reported in the results section.

In contrast, approximately 22% of our included manuscripts (8/36 articles) are based on Lopez's definition of urban sprawl: a disorderly and uncontrolled urban expansion towards peripheral areas accompanied by a decline in population density [23]. Thus, in these manuscripts, the explored dimensions are reduced to one for each manuscript, namely the previously mentioned low-density development and the dispersion of residents.

Regarding the remaining five articles that have not been mentioned, it is regrettable to note that none of them provided a definition of sprawl. Nevertheless, these articles were included in the review as they furnished an accurate description of the sprawl index that was chosen.

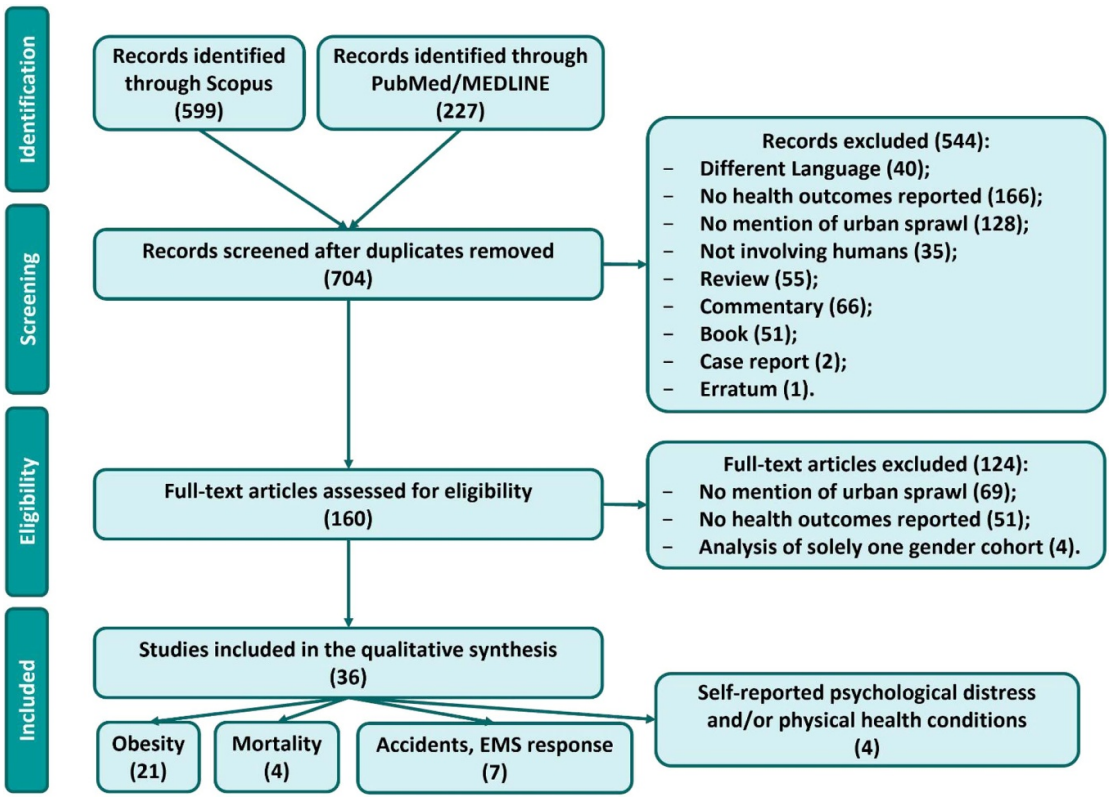

Figure 1. Flowchart representing PRISMA flow diagram of studies' screening and selection.

Figure 2. Visual representation of the geographical areas of the records included in the narrative review process.

4.2. Sprawl index

Unfortunately, the urban sprawl definition and the index used to evaluate it do not correspond perfectly. The term 'sprawl' has different meanings in different geographic regions, and it is possible to identify common characteristics in the same region over time.

Given that sprawl is a complex phenomenon, it is necessary to employ diverse indicators to assess its various dimensions. The most important exogenous variable is the county compactness/sprawl index. This index positions urban sprawl at one end of a continuum and compact development at the other [26]. Specifically, as the index value increases, the level of compactness in the analyzed area also increases. The inverse relationship between value and sprawl indicates that as the former decreases, the latter increases.

The 2002-created original index was then revised in 2010 [8, 27–29]. The revised version considers

Table 1. Characteristics and main results of the included studies (reported in the alphabetical order of the first author).

Reference article (Reference No.)	Title	Publication year	City/county/ region, country	Health outcome	Sprawl definition	Primary objective of the study	No of participants and/or cities/ counties considered	Used methodology	Year(s) of study
Arcaya *et al* [30]	Urban sprawl and body mass index among displaced Hurricane Katrina survivors	2014	US	BMI	Two characteristics of sprawl: (1) low residential density, and (2) poor street accessibility	To explore county level sprawl as a predictor of BMI	280 displaced Hurricane Katrina survivors who had little control over their neighborhood replacement	Cross-sectional	2003–2005, 2006–2007
Berrigan *et al* [31]	Urban sprawl, obesity, and cancer mortality in the United States: cross-sectional analysis and methodological challenges	2014	US	Cancer Mortality	Composite measure of features of urban form related to population density and street accessibility	To estimate associations between urban sprawl and cancer mortality in the US	935 counties	Cross-sectional	2002–2006
Congdon [32]	Explaining variations in obesity and inactivity between US metropolitan areas	2016	US	BMI	Low density or leapfrog development, with segregated land uses, low walkability, and high automobile dependence	To carry out an ecological analysis of environmental influences on variations in obesity and inactivity	993 metropolitan counties	Cross-sectional	2004
Eid *et al* [33]	Fat city: questioning the relationship between urban sprawl and obesity	2008	US	BMI	Residential sprawl is the portion of undeveloped land in the km^2 around a typical residential development in an individual's neighborhood	To determine whether the association between BMI and urban sprawl reflects the fact that people with a tendency to be obese self-select into sprawling areas	2780 males and 2881 females extracted from the National Longitudinal Survey of Youth 1979 (NLSY79)	Cross-sectional	1988–1990, 1992–1994

(Continued.)

Table 1. (Continued.)

Reference article (Reference No.)	Title	Publication year	City/county/ region, country	Health outcome	Sprawl definition	Primary objective of the study	No of participants and/or cities/ counties considered	Used methodology	Year(s) of study
Ewing *et al* [7]	Relationship between urban sprawl and physical activity, obesity, and morbidity	2003	US	BMI	Characterized by (1) a population widely dispersed in low density residential development; (2) rigid separation of homes, shops, and workplaces; (3) a lack of distinct, thriving activity centers, such as strong downtowns or suburban town centers; and (4) a network of roads marked by large block size and poor access from one place to another	To assess the relationship between urban sprawl, health, and health-related behaviors	Counties (448) and metropolitan areas (83). Adults (206 992)	Cross-sectional	1998–2000
Ewing *et al* [34]	Urban sprawl as a risk factor in motor vehicle occupant and pedestrian fatalities	2003	US	Traffic fatalities, non-fatal vehicle crashes, and pedestrian fatalities	A population widely dispersed in low-density residential development; rigid separation of homes, shops, and workplaces; a lack of distinct, thriving activity centers and a network of roads marked by very large block size and poor access from one place to another.	To determine the association between urban sprawl and traffic fatalities	448 metropolitan counties	Ecological	2000
Ewing *et al* [35]	Relationship between urban sprawl and weight of United States youth	2006	US	BMI	Ewing definition, they used their own developed sprawl index	To determine if urban sprawl is associated with BMI for US youth	8984	Cross-sectional	1997
Ewing *et al* [19]	Relationship between urban sprawl and physical activity, obesity, and morbidity—update and refinement	2014	US	BMI	Updated Ewing sprawl index which considers four dimensions: county density factors, county mix factor, county centering factor, and county street factor	To evaluate the multiple health outcomes and behaviors in terms of the updated sprawl measures	500 or more respondents	Cross-sectional	2007–2010

(Continued.)

Table 1. (Continued.)

Reference article (Reference No.)	Title	Publication year	City/county/ region, country	Health outcome	Sprawl definition	Primary objective of the study	No of participants and/or cities/ counties considered	Used methodology	Year(s) of study
Ewing *et al* [28]	Urban sprawl as a risk factor in motor vehicle crashes	2014	US	Traffic fatalities and non-fatal vehicle crashes	Updated Ewing sprawl index which considers four dimensions: county density factors, county mix factor, county centering factor, and county street factor	To update the previous county sprawl index, create revised indices that account for additional pertinent aspects, and check the indices against commuting statistics	994 metropolitan counties	Cross-sectional	2008–2011
Ewing and Hamidi [36]	Urban sprawl as a risk factor in motor vehicle occupant and pedestrian fatalities: update and refinement	2014	US	Pedestrian fatalities	Updated Ewing sprawl index which considers four dimensions: county density factors, county mix factor, county centering factor, and county street factor	To update the prior county sprawl index and determine if increasing street connection leads to a rise in traffic accidents	994 metropolitan counties	Ecological	2006–2010
Fan and Song [37]	Is sprawl associated with a widening urban–suburban mortality gap?	2009	US	Mortality	Low development density, segregated land uses, lack of significant centers, and poor street connectivity	To examine whether sprawl contributes to a widening mortality gap between urban and suburban residents	65 largest metropolitan areas; Portland metro's 71 zip code areas	Cross-sectional	2000–2009
Garden and Jalaludin [38]	Impact of urban sprawl on overweight, obesity, and physical activity in Sydney, Australia	2009	Sydney, Australia	Overweight and obesity	Metropolitan areas where large percentages of the population live in low density residential areas	To determine whether urban sprawl in Sydney, Australia is associated with overweight/obesity and levels of physical activity	7290 adults (>16 yo)	Cross-sectional	2002–2003
Garrido-Cumbrera *et al* [39]	Exploring the association between urban sprawl and mental health	2018	Seville, Spain	Self-rated health and psychological distress	Use of a new sprawl index based on the combination of six factors: density of population, cumulative residential density, coverage ratio, land use classification, residential land use percentage, and average year of construction for each area	To ascertain if urban sprawl is related to self-reported psychological distress	505 adults (16–64 yo)	Cross-sectional	2015

(Continued.)

Table 1. (Continued.)

Reference article (Reference No.)	Title	Publication year	City/county/ region, country	Health outcome	Sprawl definition	Primary objective of the study	No of participants and/or cities/ counties considered	Used methodology	Year(s) of study
Gregson [40]	Poverty, sprawl, and restaurant types influence body mass index of residents in California counties	2011	California, US	BMI	No definition	To examine the relationships between structural poverty, urban sprawl, and three types of restaurants in explaining BMI	14 205	Cross-sectional	2005–2007
Guettabi and Munasib [41]	Urban sprawl, obesogenic environment, and child weight	2014	US	BMI	Ewing definition	To determine if urban sprawl influences the BMI of the children of NLSY79 female respondents living in US metropolitan areas	2324 children (2–17 yo)	Cross-sectional	1988–2008
Hamidi *et al* [22]	Associations between urban sprawl and life expectancy in the United States	2018	US	Causes of premature death	Urban sprawl is defined as the following urban forms: (1) leapfrog or scattered development; (2) commercial strip development; (3) expanses of low-density development; and (4) expanses of single-use development	To estimate association between sprawl and life expectancy	606 metropolitan counties	Cross-sectional	2000–2010
Jalaludin and Garden [42]	Does urban sprawl impact on self-rated health and psychological distress? A multilevel study from Sydney, Australia	2011	Sydney, Australia	Self-rated health and psychological distress	Defined as metropolitan areas where large percentages of the population live in low density residential areas	To evaluate the association between self-rated health, psychological distress and urban sprawl	21 140 adults (>16 yo)	Cross-sectional	2006–2007
James *et al* [43]	Urban sprawl, physical activity, and body mass index: Nurses' Health Study and Nurses' Health Study II	2013	US	BMI	Characterized by four dimensions: low residential density; rigidly separated homes, shops, and workplaces; roads with large blocks and poor access; and a lack of well-defined activity centers	To evaluate the association between the county sprawl index and body mass index (BMI)	136 592	Cross-sectional	2000–2001

(Continued.)

Table 1. (Continued.)

Reference article (Reference No.)	Title	Publication year	City/county/ region, country	Health outcome	Sprawl definition	Primary objective of the study	No of participants and/or cities/ counties considered	Used methodology	Year(s) of study
Joshu *et al* [44]	Personal, neighbourhood and urban factors associated with obesity in the United States	2008	US	BMI	No definition, they used sprawl index developed by Ewing	To determine whether personal and neighborhood barriers differ by the level of urbanization	1818 interviews	Cross-sectional	1999–2000
Kelly-Schwartz*et al* [45]	Is sprawl unhealthy? A multilevel analysis of the relationship of metropolitan sprawl to the health of individuals	2004	US	BMI	No definition, they used sprawl index developed by Ewing	To explore the relationship between urban sprawl and health with a large dataset containing responses from 29 randomly chosen primary metropolitan statistical areas (PMSA)	9252 interviews and medical examinations	Cross-sectional	1988–1994
Lambert and Min [46]	Neighborhood environment and obesity in the Louisville, Kentucky area	2010	Louisville, US	BMI	Ewing definition	To assess whether there is a link between urban sprawl and levels of obesity	515 565 drivers	Cross-sectional	2000
Lathey *et al* [47]	The impact of subregional variations in urban sprawl on the prevalence of obesity and related morbidity	2009	US	BMI	Ewing definition, their analysis captures the subregional variability in the development patterns between the central city and the fringe suburban areas.	To examine the relationship between urban sprawl and health using a new methodological approach	3.8 millions	Cross-sectional	2003–2005
Lopez [23]	Urban sprawl and risk for being overweight or obese	2004	US	Overweight and obesity	Overall pattern of development across a metropolitan area where large percentages of the population live in lower density residential areas.	To determine if urban sprawl is a public health problem	104 084 final respondents	Cross-sectional	2000
Mobley *et al* [48]	Spatial analysis of elderly access to primary care services	2006	US	ACSCs (ambulatory care sensitive conditions)	Identified as a variable: % of the workforce who travel more than 60 min to work.	To assess ambulatory care sensitive conditions (ACSCs) admission rates with urban sprawl	6475	Ecological	1998–2000

(Continued.)

Table 1. (Continued.)

Reference article (Reference No.)	Title	Publication year	City/county/ region, country	Health outcome	Sprawl definition	Primary objective of the study	No of participants and/or cities/ counties considered	Used methodology	Year(s) of study
Mohame and Min [49]	Jurisdictional spillover effects of sprawl on injuries and fatalities	2014	Southeast Michigan, US	Accidents	No definition, they used 5 of the 6 variables firstly individuated by Ewing in 2003	To estimate how injuries and fatalities in one jurisdiction are associated with sprawl in that jurisdiction and sprawl in neighboring jurisdictions	122 jurisdictions within 7 county areas	Cross-sectional	2010
Näyhä *et al* [50]	Body mass index and overweight in relation to residence distance and population density: experience from the Northern Finland birth cohort 1966	2013	Northern Finland, Finland	BMI	Urban sprawl is characterized by inadequate walkability of streets and roads, dependence on private cars and poor accessibility to well-equipped food stores	To examine whether body mass index (BMI) and the prevalence of overweight are associated with urban sprawl	5363	Cross-sectional	2003
Restivo *et al* [20]	Urban sprawl and Health Outcome Associations in Sicily	2019	Sicily, Italy	Mortality Rate	Low population density, automobile dependence, and single-use land zoning	To formulate and validate a sprawl index for Sicilian municipalities and evaluate its association with health outcomes	110 municipalities	Ecological	2011
Ross *et al* [51]	Body mass index in urban Canada: neighborhood and metropolitan area effects	2007	Canada	BMI	3 equally weighted dimensions of sprawl: proportion of Census Metropolitan Area (CMA) dwellings that are single or detached units, dwelling density, and percentage of CMA population living in the urban core	To investigate the influence of neighborhood and metropolitan area characteristics on body mass index (BMI)	131 535	Cross-sectional	2001
Santana *et al* [52]	The link between local environment and obesity: a multilevel analysis in the Lisbon metropolitan area, Portugal	2009	Lisbon, Portugal	BMI	Defined as population density per km^2	To examine the contribution of the local environment and personal attributes to the risk of weight gain	7669	Cross-sectional	2008

(Continued.)

Table 1. (Continued.)

Reference article (Reference No.)	Title	Publication year	City/county/ region, country	Health outcome	Sprawl definition	Primary objective of the study	No of participants and/or cities/ counties considered	Used methodology	Year(s) of study
Seliske *et al* [53]	Urban sprawl and its relationship with active transportation, physical activity and obesity in Canadian youth	2012	Canada	BMI	Pattern of development whereby metropolitan areas extend over a large geographic region	To examine associations between urban sprawl and (1) active transportation, (2) MVPA, and (3) obesity	7017 respondents aged 12–19	Cross-sectional	2007–2008
Sturm and Cohen [54]	Suburban sprawl and physical and mental health	2004	US	Self-rated psychological distress, health-related quality of life, and chronic physical health conditions	Ewing definition	To investigate whether metropolitan-level suburban sprawl indicators are associated with chronic physical issues, mental conditions, and health-related quality of life	8686 observations from 38 metropolitan areas	Cross-sectional	1998, 2000–2001
Sugiyama and *et al* [55]	Residential proximity to urban centres, local-area walkability and change in waist circumference among Australian adults	2016	Australia	Waist circumference	No definition, they mentioned Ewing and Mackenbach	To examine how proximity to city center, proximity to suburban center, and local walkability were associated with change in waist circumference	3182 adults	Cross-sectional	2000–2006
Trowbridge *et al* [56]	Urban sprawl and delayed ambulance arrival in the U.S.	2009	US	EMS response time	Low-density construction, poor street connectivity, and single-use zoning that separates residential housing from civic and commercial districts	To measure the association between urban sprawl and EMS response time	954 metropolitan counties; 113 879 motor-vehicle crashes	Cross-sectional	2000–2002

(Continued.)

Table 1. (Continued.)

Reference article (Reference No.)	Title	Publication year	City/county/ region, country	Health outcome	Sprawl definition	Primary objective of the study	No of participants and/or cities/ counties considered	Used methodology	Year(s) of study
Yan *et al* [57]	How does urban sprawl affect public health? Evidence from panel survey data in urbanizing China	2021	China	Self-rated psychological distress and physical health conditions	Urban sprawl is a condition characterized by the expansion of urban areas outweighing the growth of the urban population, the dispersion of massive amounts of individuals and economic activities to the suburban areas, a reduction in land-use amplitude and population density, and a decentralized and multidimensional urban form	To examine the effects of urban sprawl on public health from the perspectives of physical and mental health	9083 observations	Cross-sectional	2011, 2013, 2015
Yeo *et al* [24]	Effects of urban sprawl and vehicle miles traveled on traffic fatalities	2014	US	Traffic fatalities	Updated Ewing sprawl index which considers four dimensions: county density factors, county mix factor, county centering factor, and county street factor	To examine the association between urban sprawl, vehicle miles traveled (VMT), and traffic fatalities.	147 urbanized areas	Cross-sectional	—
Zhao and Kaestner[58]	Effects of urban sprawl on obesity	2010	US	Body Weight	Urban sprawl includes low population density, dispersed employment, separate zones of land use and dependence on automobile for travel	To estimate the association between the proportion of a metropolitan area living in dense areas (as a proxy for urban sprawl) and the built environment, and the weight of residents in that area	National Health Interview Survey (NHIS) for each year from 1976 to 2001; Neighborhood Changing Data Base for years 1970, 1980, 1990 and 2000; Current Population Survey (CPS) March file from 1976 to 2001	Cross-sectional	1970–2000

four characteristics: residential density, land use diversity, population and employment concentration, and street connectivity.

4.2.1. Residential density

The first crucial criterion is residential densThe first crucial criterion is residential density, which is evaluated in nearly all of the chosen articles because it is a crucial indicator of urban sprawl. It consists of four variables that encompass various environmental settings: (1) gross density of urban and suburban census tracts; (2) percentage of residents living at low suburban densities; (3) percentage of residents living at medium-to-high urban densities; (4) and urban density.

4.2.2. Land use mix

The second characteristic is the diversity of land uses, which can be evaluated using one of three mixed-use measures: (1) balance between population and occupational activities within portions of a county; (2) diversity of land uses within portions of a county; and (3) accessibility of residential uses to non-residential uses at different locations within a county.

4.2.3. Population and employment centering

Urban centers are defined as densely populated urban areas, where metropolitan population and employment are typically concentrated. It is distinguished from sprawling areas by concentrations of development within or around the central business districts of historic metropolitan areas.

The presence of urban centers is associated with compactness, and their absence is associated with sprawl.

4.2.4. Street connectivity

Street connectivity exemplifies the fourth dimension. Four variables are evaluated in order to determine the relative magnitude of this item in the various environments: (1) average block size (excluding rural blocks of more than one square mile); (2) relative percentage frequency of small urban blocks with a surface of less than one-hundredth of a square mile; (3) intersection density for urban and suburban census tracts within the county (excluding rural areas with gross densities of less than 100 people per square mile); and (4) relative percentage frequency of four-way or more intersections (excluding rural tracts).

4.3. Urban sprawl and health outcomes

This literature review revealed a mixed relationship between urban sprawl and several health outcomes.

Multiple studies have indicated that urban sprawl negatively affects human health. Physical inactivity, obesity, traffic fatalities, poor air quality, residential energy consumption, emergency response times, teenage driving, a lack of social capital, private-vehicle commute distances and times, and coronary heart disease have all been linked to sprawl.

4.3.1. Urban sprawl and mortality/life expectancy

Decades of debates have surrounded the existence of health disparities between urban and suburban residents. Life expectancy and mortality are two important health indicators; a correlation between these two outcomes and urban sprawl was assessed in four of the included studies (11%).

Hamidi and Ewing viewed the examination of a relationship between life expectancy and urban sprawl as a logical continuation of the aforementioned debate, and so they attempted to evaluate it by evaluating sprawl, life expectancy, and four covariates: (1) vehicle miles traveled (VMT), (2) body mass index (BMI), (3) violent crime rates, and (4) air quality [22]. The primary limitation of this article was its inability to assess the reason why sprawl directly affects life expectancy, in addition to the indirect effects previously examined. Despite this, it was discovered that life expectancy was significantly higher in compact counties than in sprawling ones. These findings appear to be associated with greater VMT and BMI in sprawling counties, which are significant indirect agents of life expectancy differences between the evaluated urban environments. These associations could also be explained by research indicating that longer VMT is associated with a higher rate of fatal traffic accidents [59]; similarly, a higher BMI is associated with an increased risk of developing chronic diseases such as cardiovascular disease, diabetes, and cancer [7, 16, 20, 60–62]. On the other hand, Hamidi and Ewing found that violent crime and air pollution were lower in sprawling counties, likely reducing mortality risk, albeit to a lesser extent than VMT and BMI [22].

As previously stated, the urban form may play a role not only in terms of life expectancy but also in terms of mortality rates. Different county-level mortalities are proven to be attributable to urban–rural disparities [63], as opposed to the development of particular chronic diseases [64].

In studies examining the relationship between urban sprawl and mortality, sprawling counties/metropolises had higher overall and cause-specific mortality rates than compact counties/metropolises.

Each of the three studies yielded results that were partially dissimilar. The first study conducted in Sicily examined the relationship between overall and cause-specific mortality rates and urban sprawl among Sicilian municipalities [20]; metropolitan-level urban sprawl indices appeared to be higher in larger cities than in smaller ones, which may be associated with slower development of urbanization processes in the city center. After controlling for age and other mortality rates, only cardiovascular mortality rates were associated with urban sprawl. This correlation could

be explained by the prevalence of sedentary lifestyles in densely populated areas [20].

The objective of the second paper was to examine the same association as the first article among various counties in the United States and the Portland metropolitan area. In metropolitan areas, the extent of urban–suburban mortality gaps changed proportionally to the magnitude of the sprawl index, according to the findings of the latter study: in sprawling areas, people living in the urban environment have a significantly higher mortality risk than people living in the suburbs, whereas, in compact areas, there is no significant difference between the various parts of the aforementioned areas. These findings cannot be attributed to sociodemographic differences. In terms of cause-specific mortality, the excess mortality rate among urban residents appears to be associated with infectious disease-related mortality rate; this consistency may be explained by factors such as crowding and density, which increase the risk of a more rapid interpersonal transmission [37].

The third article analyzed the relationship between cancer mortality and urban sprawl and determined whether this relationship varied across the United States. The first finding was that obesity-related cancer mortality rates were either higher or unrelated to urban sprawl in more densely populated counties. Second, the consistency of the association between obesity-related cancer mortality and urban sprawl was inconsistent, with more positive associations in the southern United States for females and the central United States for males [31].

4.3.2. Urban sprawl and weight gain/exercise

As stated in the results section of this manuscript, one of the most notable characteristics is the abundance of articles focusing on the relationship between urban sprawl and obesity. The spotlight placed on obesity is justifiable, considering the substantial occurrence of individuals who are overweight or obese in both the adult and pediatric demographics. With respect to adults, the incidence of clinical obesity in the United States has increased from 12.7% in males and 17% in females during the 1970s to 27.7% and 34% in the respective genders during the 2000s [65]. According to recent research, the present scenario of events appears to be more dire, with a prevalence rate of 41.8% observed among both genders during the period spanning from 2017 to March 2020 [66]. Similarly, the prevalence of childhood obesity has increased in recent years. The World Health Organization calls childhood obesity 'one of the most serious public health challenges of the 21st century' [67]: 17% of US 2-to-19-year-olds are obese, reaching 19.7% in the period spanning from 2017 to March 2020 [66].

Research on obesity started aiming at environmental, cultural, and socioeconomic reasons for caloric imbalance. In fact, 58% of the included articles (26/36 manuscripts) investigated obesity as a health outcome. The incidence of obesity, BMI, and waist circumference were used as obesity surrogates due to their known association with the outcome in question while acknowledging the potential for both underestimation and overestimation of obesity condition when utilizing BMI as a surrogate measure in populations different from the adult Caucasian males [68].

Greater levels of urban sprawl were associated with a greater likelihood of being overweight or obese, according to nearly all of the articles analyzed [7, 19, 23, 32, 33, 38, 40, 41, 44, 50]. Residents of sprawling counties were more likely to walk less, weigh more, and have a higher prevalence of hypertension than residents of compact counties. According to Ewing and Arcaya, this association does not appear to be affected by the hypothesized phenomenon of self-selection into sprawling/compact counties, nor does it appear to be confounded by socioeconomic differences between sprawling and compact area residents [7, 19, 30, 35]. The absence of a correlation between obesity and self-selection of residing in sprawling areas has been questioned by Eid *et al* [33]. To investigate the potential role of self-selection, the authors focused on two main factors in the built environment that previous research has linked to obesity: the first factor is the 'residential sprawl', quantified using Burchfield *et al*'s [69] remote-sensing land cover data, while the second is the 'land use mix' status. The results indicate a positive correlation between obesity and residential sprawl, as well as a negative correlation with land use mix in men. These correlations are weaker among women. After adjusting for demographic variables such as age and race, the correlation persists; moreover, it appears that black and Hispanic males and females have higher BMIs than their white counterparts. When adjusting for the full set of individual characteristics, the association between obesity and urban sprawl disappears, as well as the correlation between obesity and land use mix. These results confirm that residents of sprawling neighborhoods have higher BMIs than those in compact areas; at the same time, through a different approach, they ascertained that the individuals residing in expansive geographical regions exhibited an elevated BMI as a result of their inherent predisposition to weight gain and not because of their residential environment.

According to James *et al* [43], there is a statistically significant correlation between urban sprawl and women's BMI. Specifically, for each unit increase in the county sprawl index, it was estimated that the BMI would decrease. Moreover, a positive correlation was discovered between the county sprawl index and women's physical activity: the more compact the area, the more interested women are in physical activity. These results, derived from a geographically diverse sample of women spanning a wide age range, suggest that women residing in more compact counties, whose urban form is better defined and designed, had

lower BMIs and were more likely to engage in outdoor physical activity.

Ewing *et al* [35] demonstrated that, in the United States, children living in sprawling counties are more likely to be overweight than those living in compact counties. At the same time, Guettabi *et al* [41] adopting the Ewing sprawl index and the distance to the nearest micro/metropolitan area to measure urban sprawl, revealed that proximity to the nearest micro/metro has no discernible impact, while compactness exerts a detrimental influence on child BMI for both the complete sample and the subgroup that migrated from one county to another. Child BMI is connected with the mother's BMI, education, and marital status. Females exhibit a greater degree of compactness in comparison to the entire sample, while males do not display any statistically significant measures of urban sprawl or distance. Our study revealed that the impact of urban sprawl and distance from the urban hierarchy is more pronounced on girls as compared to boys. The observed differences could potentially be attributed to the ways in which girls and boys interact with their built environment. Boys actively commute more than girls [70]. Compared to counties with large populations, children living in sprawling areas tended to engage in less physical activity and more sedentary activities, such as television viewing and other indoor recreation. Because parks and fitness facilities are further away, urban sprawl may reduce the amount of time available for physical activity. It may also affect diets by increasing the distance to the nearest supermarkets; in addition, the conversion of farmland to urban uses may increase the price of nutritious food.

Zhao and Kaestner [58] examined how changes in the metropolitan areas population distribution affected obesity and found that population loss in the central city and growth in the suburbs increase obesity. Overall, the findings of this study indicate that urban sprawl contributed to a modest increase in obesity. The Santana-led research team analyzed identical items in the Lisbon metropolitan area [52]. This study revealed a tendency for residents of walking/running-friendly areas to engage in physical activity, albeit without statistical significance. In line with the findings of the previous two studies, Sugiyama *et al* [55] discovered that living close to the city center appears to be protective against excessive BMI increase, but surprisingly and contrary to expectations, living close to the suburban center was associated with higher BMI rates. Despite the presence of a train station or bus station in each suburban center, these transportation hubs may not be adequate for promoting active travel.

Nonetheless, there were five studies with contradictory results. In particular, Seliske *et al* [53] discovered that a high degree of urban sprawl was associated with higher odds of physical activity and greater use of active transportation, but not with obesity. Kelly-Schwartz *et al* [45] found no significant influence of urban sprawl on obesity, stating that their findings suggest that the relationship between urban sprawl and obesity is more complex than as it is reported by Ewing *et al*; in fact, they suggest that the various dimensions of urban sprawl have varying and potentially conflicting impacts on public health. Similar results were found in the studies conducted by Ross *et al* [51], Lambert and Min [46], and Lathey *et al* [47], in which a strong correlation was found between the walkability index—one of the sprawl index indicators—and BMI. However, apart from this association, no correlation was found between other urban sprawl indicators and the aforementioned outcome. Not directly correlated with population density, which did not appear to be a significant determinant of citizens' walking propensity, the walkability index in particular reflects the accessibility to common places where social interaction is possible. This discordance may be due to the different approaches and the different geographical scale: while many articles developed and analyzed county-scale compact-to-sprawling contexts, the discordant articles used a metropolitan approach, so the magnitude of their findings may differ.

If the association between urban sprawl and obesity risk suggested by the majority of these studies is real, then urban sprawl may be contributing to a serious public health issue. In light of the contradictory results, however, additional research would be required to assess the association between urban sprawl and the risk of being obese after adjusting for major possible confounding factors and socioeconomic deprivation.

4.3.3. Urban sprawl and ambulance arrival, ambulatory care, and pedestrian and motor accidents

One of the most prominent characteristics of urban sprawl is the lack of street connectivity, as well as the high number of travelled kilometers. Increased automobile use as a result of sprawl has negative health effects, resulting in higher rates of inactivity and obesity, as well as an increase in pedestrian injuries and fatalities. In addition, the danger, duration, and efficiency of personal vehicle trips may influence the frequency of access to primary care services—particularly among the elderly and the poor—excluding emergency medical dispatches. This may be because the elderly and the poor have fewer resources to overcome intrinsic environmental obstacles. Considering this issue, older residents of sprawling areas may be at a greater risk of unnecessary admissions for ambulatory care sensitive conditions (ACSCs); additionally, EMS response time may be compromised, particularly when it is most needed (such as in the case of major traumas or cardiac arrest) [48, 71]. Urban sprawl appears to have a disproportionately negative effect on the physical

health of the elderly and the poor, given that street accessibility and connectivity appear to be key components in promoting walking habits [26, 72].

Our review procedure allowed us to include two articles concerning the evaluation of these associations. Trowbridge *et al* [56] discovered that there is indeed a correlation between urban sprawl and increased EMS response time; results indicated that the probability of an ambulance dispatch delay is twice as likely in sprawling counties compared to more compact counties. Similarly, Mobley *et al* [48] found that living in a sprawling area with a greater number of travelled kilometers was statistically positively associated with the number of ACSCs admissions; it has been estimated that there is an increase of three admissions for each standard deviation increase in the proportion of citizens whose jobs require more than one hour of daily travel.

The included articles suggest that living in a sprawling area may have a negative impact on the elderly's access to preventive care services and on EMS response times.

Concurrently, the relationship between transportation safety and land use sprawl should be considered. According to the results, five of the thirty-six articles examined the relationship between sprawl and traffic, pedestrian, motor, and overall accidents. Three of the included articles are from Ewing *et al* [28, 34, 36], and the recent ones are an update of evidence in light of the adjusted sprawl index. In their first report published in 2003, Ewing *et al* analyzed the relationship between sprawl and three dependent variables: the all-mode fatality rate (which included fatal crashes involving private motor vehicles, buses, trains, taxis, bicycles, and pedestrians), the county-level traffic fatality rate, and two county-level traffic fatality rates that were specific to pedestrians. The sprawl index was found to be significantly correlated with the all-mode traffic fatality rate, indicating that more compact counties had a lower rate of traffic fatalities [56]. During the years 2014 and 2015, the authors discovered that the correlations they obtained were comparatively weaker than those obtained from the previous sprawl index, albeit still possessing statistical significance [28, 36]. Overall, the findings of their study suggest that there is a causal relationship between urban sprawl and both traffic fatalities and pedestrian accidents, both directly and indirectly mediated by VMT. In addition, Mohamed *et al* [49] demonstrate that sprawl in a given jurisdiction increases the number of injuries and fatalities in that jurisdiction and surrounding jurisdictions. This may be related to the length of existing roadway miles. Additionally, vehicle speed may play a significant role in fatality rates and pedestrian accidents. For instance, sprawling communities typically have broad, lengthy streets that encourage excessive speed.

Yeo *et al* [24] aimed at assessing whether VMT are the only explanatory variable in the association between urban sprawl and traffic fatalities. Their results confirmed that VMT certainly plays a role in the fatality rate, having a positive direct correlation; its role, however, seemed to be less important than the urban sprawl itself, given that sprawl directly increased traffic fatalities more than VMT did. These findings suggest that focusing on the miles traveled by each individual living in a sprawling area may have been overemphasized in order to reduce traffic fatalities, suggesting to search for other potential factors on which public health should focus.

4.3.4. Urban sprawl, subjective health ratings, and psychological distress

Mental disorders are one of the top ten leading causes of global burden, and there is no evidence that the burden has decreased globally over the past 30 years [73]. The social and physical characteristics of each geographic region may influence mental health. Psychological distress has been linked to the physical characteristics of a neighborhood (such as vandalism, safety, and vacant housing) [74], while anxiety has been linked to overcrowded areas and the perception of crime and violence [75, 76]. Depression has been linked to densely populated cities, perceptions of violence and crime, deprivation in the neighborhood, and social isolation [75–78].

Based on the aforementioned premises, Yan *et al* [57] conducted a study to examine the impact of urban sprawl on public health in China. The study collected population data pertaining to mental health through the administration of the abbreviated version of the Center for Epidemiological Studies Depression scale (CESD-10) [79]. The level of urban sprawl was determined using the methodology established by Fulton *et al* [80], which considers the rate of expansion of urban built-up areas and urban population growth. The results of benchmark regression analysis indicate that there exists a statistically significant adverse impact of sprawl on the physical and mental well-being of the participants. Mental health is notably impaired among the female population, other than amongst young individuals and adults, but not among those aged 75 years and above. Those with educational backgrounds below the tertiary level exhibit a notable decline in mental health during assessments. Surprisingly, in relation to economic status, solely individuals with low incomes exhibit no apparent effect on their psychological well-being.

Jalaludin and Garden [42] sought to determine the relationship between urban sprawl and self-reported health and psychological distress among Sydney residents. After adjusting for individual- and metropolitan-level covariates, a positive association was found between urban sprawl and perceived health, but a negative association was found between urban sprawl and psychological distress. On the other hand, there were statistically significant associations

between socio-demographic income levels, employment, and perceived health and psychological distress and a few of the neighborhood factors analyzed (perception of safety in the area where participants reside, perception to trust neighbors). This article's main limitation was the assumption that the sprawl index could be calculated solely with the evaluation of population density, without the evaluation of the remaining three items; this assumption may have compromised the statistical significance of some results.

Sturm and Cohen [54] conducted a study that examined the correlation between urban sprawl and various public health issues, such as self-reported psychological distress. The findings are similar to those of the previously-mentioned study. The study analyzed data from 38 metropolitan neighborhoods in the United States. The results revealed that the sprawl index is an accurate indicator of health-related quality of life and the amount of long-term medical conditions. However, there were no statistically significant or strong correlations observed between the sprawl index and the overall incidence of psychological distress or the Mental Health Inventory (MHI-5) [81]. Garrido-Cumbrera *et al* [39] aimed to explore the correlation between urban sprawl and mental health in the metropolitan region of Seville, Spain. Preliminary findings of their study suggested a negative correlation between the degree of urban sprawl and psychological distress, as evidenced by the Spearman and Pearson correlation coefficients computed between the sprawl index and the General Health Questionnaire (GHQ-12), a tool utilized to evaluate self-reported mental health [82]. Compact areas are more susceptible to perceiving lower mental health in contrast to mildly sprawled neighborhoods. In contrast to correlation analyses, the results of the stepwise regression analysis revealed that, once various socio-demographic variables alongside the sprawl index were included, only the employment status resulted statistically significant. The conclusion is that differences in the chance to suffer psychological distress are a result of the individual's employment status rather than the degree of urban sprawl.

In contrast to commonly held assumptions, whereas there do exist correlations between mental health and various socio-economic determinants such as poverty, unemployment, social isolation, and significant life events, it appears that the relationship between psychological distress and urban sprawl is far from being straightforward. Therefore, additional research is strongly encouraged.

5. Conclusions and study limitations

'Progressive trends in architecture and urban planning, including the green building movement, smart growth, and new urbanism, grew out of environmental and social goals but often promoted health design (sometimes incidentally, sometimes by intent)' [83]; with these words, Jackson *et al* emphasized the significance of urban planning that takes architectural, social, and health needs into account.

Urban sprawl appeared to be a determinant of health in the majority of outcomes examined; therefore, it is necessary to promote alternatives to sprawling patterns when developing urban areas.

Nevertheless, this review had several limitations. First, we were unable to conduct meta-analyses due to the diverse methods employed by the included studies.

There is a general lack of uniformity: urban sprawl is loosely defined and frequently corresponds to slightly different combinations of items within sprawl indexes.

Urban sprawl is frequently defined in terms of land use diversity (or lack thereof) and population concentration (or lack thereof) [19].

The confined inclusion of articles following a cross-sectional or ecological study design has to be considered a limit. Nevertheless, upon closer examination of the reasons for each record exclusion, it emerged that none of the articles applied a prospective design. In light of this, we believe it is imperative to advocate for conducting a cohort study to reveal a causal relationship between urban sprawl and health outcomes and, thus, to go beyond the mere association and assess the reason why sprawl has a direct impact on human health.

Another possible limitation of this review is related to the composition of the query, which undoubtedly encompasses a plethora of expressions that pertain to different health outcomes, yet may not be entirely comprehensive. Nonetheless, we are optimistic that our investigation has successfully retrieved a significant portion of the documents related to the outcome we aimed to analyze.

One factor that has prevented a comprehensive assessment of the phenomenon is the evident research gap in our understanding of the connections between Urban Sprawl and several health outcomes in low- and middle-low-income countries. This research gap is particularly evident in referral to the African and Asian continents, except for the article authored by Yan *et al* [57]. Our recommendation is to incentivize the conduction of research studies in regions experiencing rapid urban sprawl [84–88], to assess both similarities and differences, as well as potential emergencies.

Finally, most studies have examined the multidimensional phenomenon of urban sprawl at the county level, which includes broad geographical areas consisting mainly of noteworthy urban centers surrounded by broad suburban environments. It is imperative to acknowledge that the practice of treating each county as a uniform entity and attributing a single health outcome value and sprawl index to each county is a constraint that warrants consideration. It is crucial to strategize adjustments for specific

characteristics as well as for the different built environments and urban plans.

Overall, we believe that after a distinct urban sprawl definition and a well-calibrated sprawl index, the evaluation of this phenomenon, alongside further adopted indicators and factors pertaining to physical and mental health in urban areas, could assist local governments, policymakers, health professionals, and architects in defining all the necessary measures to protect public health and enhance life quality across cities and counties.

Data availability statement

No new data were created or analyzed in this study.

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