Social inequalities in health within the City of Milan (Lombardy Region, Northern Italy): An ecological assessment

Le disuguaglianze di salute nella città di Milano: una valutazione ecologica

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Abstract

Objectives: to document existing geographical inequalities in health in the city of Milan (Lombardy Region, Northern Italy), examining the association between area socioeconomic disadvantage and health outcomes, with the aim to suggest policy action to tackle them.

Design: the analysis used an ecological framework; multiple health indicators were considered in the analysis; socioeconomic disadvantage was measured through indicators such as low education, unemployment, immigration status, and housing crowding. For each municipal statistical area, Bayesian Relative Risks of the outcomes (using the Besag-Yorkand-Mollié model) were plotted on the city map. To evaluate the association between social determinants and health outcomes, Spearman correlation coefficients were estimated.

Setting and participants: residents in the City of Milan aged between 30 and 75 years who were residing in Milan as of 01.01.2019, grouped in 88 statistical areas.

Main outcomes measures: all-cause mortality, type-2 diabetes mellitus, hypertension, neoplasms, respiratory diseases, metabolic syndrome, antidepressants use, polypharmacy, and multimorbidity.

Results: the results consistently demonstrated a significant association between socioeconomic disadvantage and various health outcomes, with low education exhibiting the strongest correlations. Neoplasms displayed an inverse social gradient, while the relationship with antidepressant use varied.

Conclusions: these findings provide valuable insights into the distribution of health inequalities in Milan and contribute to the existing literature on the social determinants of health. The study highlights the need for targeted interventions to address disparities and promote equitable health outcomes. The results can serve to inform the development of effective public health strategies and policies aimed at reducing health inequalities in the city.

Keywords: health inequalities, social determinants of health, ecological analysis, disease mapping, social epidemiology

Riassunto

Obiettivi: documentare le disuguaglianze geografiche esistenti nei risultati sanitari nella città di Milano, con l'obiettivo di suggerire azioni politiche per affrontarle.

Disegno: lo studio ha utilizzato un approccio ecologico per esaminare l'associazione tra svantaggio socioeconomico ed esiti di salute, utilizzando diversi indicatori di salute. Lo svantaggio socioeconomico è stato misurato attraverso bassa istruzione, disoccupazione, status di immigrazione e sovraffollamento abitativo. I rischi relativi bayesiani riferiti a ciascun indicatore sono stati proiettati sulla mappa della città utilizzando il modello di Besag-York-Mollié. Per valutare l'associazione tra determinanti sociali ed esiti di salute, sono stati stimati i coefficienti di correlazione di Spearman.

Setting e partecipanti: residenti nella città di Milano di età compresa tra 30 e 75 anni al 01.01.2019, suddivisi in 88 aree statistiche.

Principali misure di outcome: mortalità per tutte le cause, diabete mellito di tipo 2, ipertensione, neoplasie, malattie respiratorie, sindrome metabolica, uso di antidepressivi, consumi farmaceutici e multimorbilità.

Risultati: i risultati hanno dimostrato un'associazione significativa tra svantaggio socioeconomico e i diversi esiti indagati, con le correlazioni più forti in relazione al grado di istruzione. Le neoplasie hanno mostrato un gradiente sociale inverso, mentre la relazione con l'uso di antidepressivi è risultata meno stabile.

Conclusioni: I risultati raggiunti forniscono indicazioni utili circa lo stato delle disuguaglianze di salute nella città di Milano. Le evidenze forniscono una comprensione più approfondita sulla distribuzione delle disuguaglianze sanitarie a Milano e contribuiscono alla letteratura esistente sui determinanti sociali della salute.Lo studio sottolinea la necessità di interventi mirati per affrontare le disparità e promuovere equità nelle condizioni di salute. I risultati possono servire per informare lo sviluppo di strategie di salute pubblica e politiche efficaci volte a ridurre le disuguaglianze di salute nella città.

Parole chiave: disuguaglianze di salute, determinanti sociali di salute, analisi ecologica, *disease mapping*, epidemiologia sociale

What is already known

- **Health inequalities are sizeable within cities, with socially disadvantaged areas exhibiting worse outcomes compared to better-off neighbourhoods.**
- **Despite a widespread knowledge, inequalities continue to exist and sometimes widen.**

What this study adds

- **An ecological analysis using routinely collected data from local health and social institutions can effectively unveil geographical disparities in health.**
- **Specific knowledge concerning the spatial distribution of several health outcomes is reached, together with their association with area socioeconomic profile.**

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Background

A vast body of evidence has highlighted how social, economic, and cultural factors impact health conditions within a population, contributing to shaping differences in health across social strata. In this regard, the World Health Organization defines the social determinants of health as "the non-medical factors that influence health outcomes; [...] the conditions in which people are born, grow, live, work and age and the wider set of forces and systems shaping the conditions of daily life".[1] This perspective encompasses social aspects that centre around individuals' positions within the social hierarchy.[2] Consequently, lower life expectancy, higher disease rates, and diminished quality of life are more prevalent in lower social strata.[3] The concept of the social gradient in health inequalities asserts that differences in health conditions are not solely attributed to the lack of resources, such as absolute poverty. They also stem from individuals' relative status within society.[4,5] Socioeconomic stratification, influenced by factors like education, occupation, income, gender, and race/ethnicity,[6] leads to unequal access to valuable resources, including financial means, knowledge, social status, influence, and advantageous social networks, which can be utilized for the benefit of one's health.[7] Understanding the factors contributing to the social gradient also necessitates an examination of the impact of the local context in which individuals reside. Studies have confirmed the existence of various characteristics within the social and physical environment that can independently influence health, regardless of people's socioeconomic status and lifestyles.[8] Therefore, concerning the spatial distribution of health inequalities, disparities in health conditions among neighbourhoods are not solely attributable to the concentration of individuals with similar characteristics in a particular area (referred to as the compositional effect), but they also result from the characteristics inherent to the area itself.[9] Several urban environmental characteristics have been identified as influential factors in individual health outcomes. These include walkability,[10] the food environment,[11] availability of green spaces,[12] levels of air pollution,[13] area-level poverty,[14] social cohesion,[15] crime rates,[16] and collective lifestyles.[17,18] These factors have been conceptualized as drivers of individual health outcomes,[19] contributing to the establishment of neighbourhood (or contextual) effects on health.[20]

Based on the aforementioned information, this study aims to examine the patterns of health inequalities within a particular context, specifically the Municipality of Milan (Lombardy Region, Northern Italy). An ecological assessment of the association between health outcomes and the contextual socioeconomic dimension was performed, based on the joint use of administrative healthcare data and territorial socioeconomic information from the national census. The study seeks to investigate the distribution of various health outcomes – such as physical health conditions, mental health, mortality, medicine use – across the city areas and its association with the aggregate area socioeconomic profile, identified by multiple dimensions.

While the selected indicators do not allow for the assessment of an individual social gradient in the investigated health outcomes or the differentiation between compositional and contextual effects, they serve as an initial step towards exploring the existence and magnitude of health inequalities across neighbourhoods within the city of Milan. This preliminary investigation can help identify priorities for future research and inform the local policy agenda. By highlighting the variations in health outcomes and their association with neighbourhood-level socioeconomic factors, this study sets the stage for deeper investigations to understand the underlying mechanisms and develop targeted interventions to address health disparities in the city.

Materials and methods

Study population

The study population consisted of individuals aged between 30 and 75 years who were residing in Milan as of 01.01.2019, as extracted from the civil registry. The sample size for the study was 798,078 individuals. The chosen age range aimed to exclude younger individuals, as their socioeconomic impact on health conditions may not have fully manifested yet. Additionally, the older population was excluded due to the diminishing influence of socioeconomic conditions on health outcomes and health inequalities at older ages.[21,22] The study obtained information on health outcomes from the *Administrative Healthcare Databases* (AHD) maintained by the *Agency for Health Protection of the Metropolitan City of Milan* (ATS of Milan). The databases provided data on age, sex, and residential address for each individual. The residential addresses were geographically referenced to one of the 88 neighbourhoods that make up the city of Milan, which were chosen as the unit of analysis. The division of neighbourhoods was based on administrative boundaries known as Local Identity Cores (*nuclei di identità locale*, NIL), which are identified by the aggregation of contiguous census blocks. These neighbourhoods are defined by historical or project-specific characteristics that distinguish them from one another, with an average size of 2.1 km^2 and an average population of 15,863 individuals in 2018. The locations of the city neighbourhoods can be found in Fig-

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ure S1 (see online Supplementary Materials). The final analyses were conducted on 87 neighbourhoods, excluding one neighbourhood that had no inhabitants, which was the urban park 'Parco Sempione' located in the historic centre of Milan.

Variables of interest and data sources

From the range of available indicators, nine measures of poor health have been chosen. These indicators include all-cause mortality, the prevalence of type-2 diabetes mellitus (henceforth diabetes), hypertension, neoplasms (cancerous growths), respiratory diseases, and metabolic syndrome. Additionally, the proportion of individuals using antidepressants, the prevalence of polypharmacy (the concurrent use of multiple medications by a patient for his or her health conditions), and the prevalence of multimorbidity (the coexistence of two or more chronic diseases in a single individual) were considered. Each of these indicators captures distinct dimensions of population health. All-cause mortality serves as a straightforward and direct indicator of the overall health status of a population;[23] non-communicable diseases (diabetes, hypertension, neoplasms, respiratory diseases) are the primary causes of illness and death in Europe and Italy;[24] metabolic syndrome – a cluster of cardiometabolic risk factors such as increased blood pressure, high blood sugar, excess body fat around the waist, and abnormal cholesterol or triglyceride levels – although not classified as a specific disease, is associated with an increased risk of developing various chronic conditions, including cardiovascular diseases, diabetes, and neoplasms. The use of antidepressants serves as a proxy for assessing the mental health of the population. Polypharmacy and multimorbidity, on the other hand, highlight the burden of chronic diseases within the population, potentially indicating inadequate preventive measures and a higher prevalence of multiple health issues among individuals facing specific health disadvantages.[25,26]

Mortality data was obtained from the Register of Causes of Death. The presence of chronic conditions such as diabetes, hypertension, neoplasms, respiratory diseases, metabolic syndrome, and multimorbidity was determined by querying the AHD using the criteria established by the Lombardy Region to identify individuals affected by chronic conditions (details concerning the criteria followed to detect the presence of chronic conditions can be found in the 2017 Lombardy Region's deliberation No. X/6164). The use of antidepressants was identified based on the consumption of at least 10% of Defined Daily Doses[27] of antidepressants in 2019. Polypharmacy was identified as the proportion of individuals using at least three different ATC code drugs[28] in the last three months of the year. Both measures were obtained by querying the Pharmaceutical Consumption Database, which includes information from pharmacies, hospitals, and local health authorities, covering all three channels of medicine supply. To account for variations in the demographic composition of different neighbourhoods, all the health outcomes were standardized by sex and age (using five-year age groups). The standardization process utilized the distribution of the overall city population as a reference, following the direct standardization method.

Within the national census, four socioeconomic indicators were selected at the neighbourhood level, representing distinct dimensions of area deprivation that may overlap to some extent. These indicators include the proportion of individuals with low educational attainment (i.e., maximum primary education), the unemployment rate, the percentage of immigrants in each area, and a measure of housing overcrowding. Education is the indicator mostly associated with health.[29] It directly influences health by promoting higher levels of health literacy, which enables individuals to make informed choices and adopt healthier behaviours such as engaging in physical activity, maintaining a nutritious diet, and reducing alcohol and tobacco consumption.[30] Indirectly, a higher level of education can lead to better employment prospects, which are associated with lower physical risks[31] and lower levels of stress[32]. Moreover, higher income resulting from education can provide access to health-relevant resources such as safe housing, healthy food options, and healthcare services.[33] Unemployment is linked to an increased risk of morbidity and mortality.[34] Economic deprivation resulting from unemployment can limit individuals' life choices and access to essential goods and services that are beneficial for health.[35] Being unemployed might also impact the psychosocial domain (e.g., stigma, social isolation, and loss of self-worth), and it is associated with poor mental health, anxiety, and depression.[36] Additionally, unemployment has been linked to negative physical health outcomes such as high blood pressure, elevated cortisol levels, and an increased risk of heart diseases.[37] Immigration status represents another dimension of everyday inequality, as immigrants may encounter disadvantaged circumstances throughout their lives, resulting in lower health indicators and life expectancy compared to the native population.[38] Being an immigrant can restrict behavioural choices and directly impact the effects of other social determinants on health outcomes.[39] Overcrowding is a housing related indicator of material resources and could also affect health directly, especially in relation to mental health[40] and the spread of infectious diseases[41]. The use of aggregate measures of individual socioeconomic status is a valuable and reliable indicator of area disadvantage, as the clustering of disadvantaged individuals in specific neighbourhoods is not a random occurrence but rather a consequence of the unattractiveness of such areas.[42] Individuals with lower socioeconomic status are more likely to reside in economically affordable areas that often lack essential services and amenities such as parks, schools, grocery stores, and healthcare facilities.[43] These areas may also exhibit physical disorder, including abandoned buildings, noise, graffiti, vandalism, filth, and disrepair, as well as social disorder, such as crime, loitering, public drinking or drug use, conflicts, and indifference.[44] Consequently, although to varying degrees, the concentration of individuals with these characteristics may reflect the presence of individuals with limited economic resources and qualifications who can only afford to live in less desirable areas such as working-class neighbourhoods, council estates, peripheral areas, and similar locations.

Neighbourhood-level socioeconomic measures were derived from the 2011 Italian Population and Housing Census, which remains the most recent official source of aggregated socioeconomic data at the sub-municipal level at the time of writing. The following measures were calculated for each neighbourhood:

- **Low education:** this measure represents the percentage of individuals aged 15 or older with at most a primary education out of the total population within the same age range;
- **Unemployment:** this measure indicates the percentage of individuals within the working age range (15-64 years) who are actively seeking employment for the first time or seeking new job opportunities, out of the total workforce population;
- **Immigration:** this measure represents the percentage of non-Italian residents within the total population of the neighbourhood;
- **Housing crowding:** this measure is calculated as the average number of occupants per 100 m^2 of residential space in each neighbourhood.

Statistical analyses

First, descriptive statistics for the variables of interest are provided. Subsequently, socioeconomic and health indicators were plotted on the city map. As regards health outcomes, Bayesian Relative Risks (BRRs) were calculated using the Besag-Yorkand-Mollié (BYM) model, a lognormal Poisson model which contains a random-effect component for non-spatial heterogeneity and a component that accounts for spatial autocorrelation (i.e., observations of the neighbouring areas may be spatially correlated more than the observations of the remote areas).[45] This model is widely considered an appropriate tool for small area disease mapping, and it is specifically suited for estimation based on small numbers of events and small at-risk populations,[46] as in the case of some neighbourhoods in the study area. This model assumes that the observations of a certain variable Y_i, are conditionally independently Poisson distributed.[45] Here, Simpson and colleagues' BYM2[47] was used, a new parametrization of the BYM model which makes parameters interpretable and facilitates the assignment of meaningful penalized complexity priors. To apply the BYM2, the observed cases of the diseases indicators were modelled for each neighbourhood i by using a Poisson distribution with mean of the expected cases (E_i) and the relative risk (θ_i) in neighbourhood i, where the θ_i quantifies whether neighbourhood i has higher risk ($\theta_i>1$) or lower risk ($\theta_i<1$) than the average risk ($\theta_i=1$) in the standard population. The relative risk estimates were obtained and the effect of the population of each neighbourhood was quantified estimating the following spatial model:

$$Y_i / \theta_i \sim \text{Poisson}(E_i\,\theta_i), \qquad i=1,2,\ldots,87$$
$$\log(\theta_i) = \beta_0 + \beta_1\, x_i + u_i + v_i$$

where:
$\log(\theta_i)$ is logarithm of the relative risk;
β_0 is the intercept which represents the overall risk in the neighbourhood i;
β_1 is the coefficient of the covariate;
u_i is the random effect modelled by the conditionally autoregressive (CAR) distribution in district i;
v_i is an unstructured spatial effect which is modelled as normal independent identically distributed.

As a robustness check, the spatial distribution of health outcomes was also assessed using Standardized Incidence Ratios (SIRs). SIRs are defined as the ratio of observed cases to expected cases and allow for the examination of territorial heterogeneity in the outcomes without considering spatial autocorrelation.

After separately mapping the independent and dependent variables, the second step involved calculating Spearman rank correlation coefficients (ρ) to examine the association between the sex- and age-adjusted socioeconomic indicators and the selected health outcomes. The Spearman coefficient is suitable for detecting monotonic relationships and does not rely on the assumption of normal data distribution.[48] This approach was well-suited for the analysis as it accounted for the presence of outliers and the non-normal distribution of the data.

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Domain	Overall City Estimates (%)	Numerator (N.)	Definition	Data Sources
Exposures				
Low Education	20.0	234,881	Residents 15+ years old with at most primary education / Total number of residents 15+ years old * 100	2011 Census
Unemployment	6.9	31,919	Residents 15-64 years old unemployed / Total number of residents 15-64 years old * 100	2011 Census
Immigration	15.0	176,303	Non-Italiana residents / Total number of residents *100	2011 Census
Housing crowding	2.3	1,242,123	Total number of residents / 100 m^2 of residential space	2011 Census
Outcomes				
All-cause mortality	0.4	2,954	Number of deaths (all causes) / Total number of residents *100	Register of Causes of Death (ReNCaM)
Diabetes	5.0	39,739	Number of residents with type-2 diabetes mellitus / Total number of residents *100	Administrative Healthcare Databases: Banca Dati Assistito (BDA)
Hypertension	14.3	114,103	Number of residents with hypertension / Total number of residents *100	Administrative Healthcare Databases: Banca Dati Assistito (BDA)
Neoplasms	7.1	56,916	Number of residents with neoplasms / Total number of residents *100	Administrative Healthcare Databases: Banca Dati Assistito (BDA)
Respiratory diseases	3.2	25,766	Number of residents with respiratory diseases / Total number of residents *100	Administrative Healthcare Databases: Banca Dati Assistito (BDA)
Metabolic syndrome	1.7	13,406	Number of residents with metaboliv syndrome / Total number of residents *100	Administrative Healthcare Databases: Banca Dati Assistito (BDA)
Antidepressants use	4.0	31,981	Number of residents with at least 10% of Defined Daily Doses of antidepressants *100	Administrative Healthcare Databases: Pharmaceutical Consumption Database
Polypharmacy	6.9	55,168	Number of residents using at least three different ATC code drug in the last three months of the year / Total number of residents *100	Administrative Healthcare Databases: Pharmaceutical Consumption Database
Multimorbidity	16.5	131,547	Number of residents with two or more chronic diseases / Total number of residents *100	Administrative Healthcare Databases: Banca Dati Assistito (BDA)

Table 1. Percentages of individuals classified as poorly educated, unemployed, immigrants, living in overcrowded conditions, and the prevalence (per 100 residents/year) of health outcomes. City of Milan, 2019. Sample: 798,078 persons.
Tabella 1. Percentuale di individui con bassa istruzione, disoccupati, stranieri, residenti in condizioni di sovraffollamento, e prevalenza (per 100 residenti/anno) degli esiti di salute. Comune di Milano, 2019. Campione: 798.078 persone.

Results

Descriptive statistics for the variables of interest are presented in Table 1.

As regards to socioeconomic indicators, these were categorized into five classes using Jenks' Natural Break Classification,[49] a method that minimizes the average deviation within classes while maximizing the deviation from the means of other classes. This approach aims to highlight significant differences in the distribution of the variable based on inherent groupings in the data. It is a preferable alternative to quantile division, which assigns an equal number of units to each class and may not capture the true distribution patterns in non-linearly distributed data.[50] The maps in Figure 1 reveal an uneven distribution, with a higher concentration of socioeconomic disadvantage observed in the outskirts of the Municipality of Milan. This pattern aligns with the existing understanding of social inequalities in the city, characterized by a clear division between an affluent city centre and

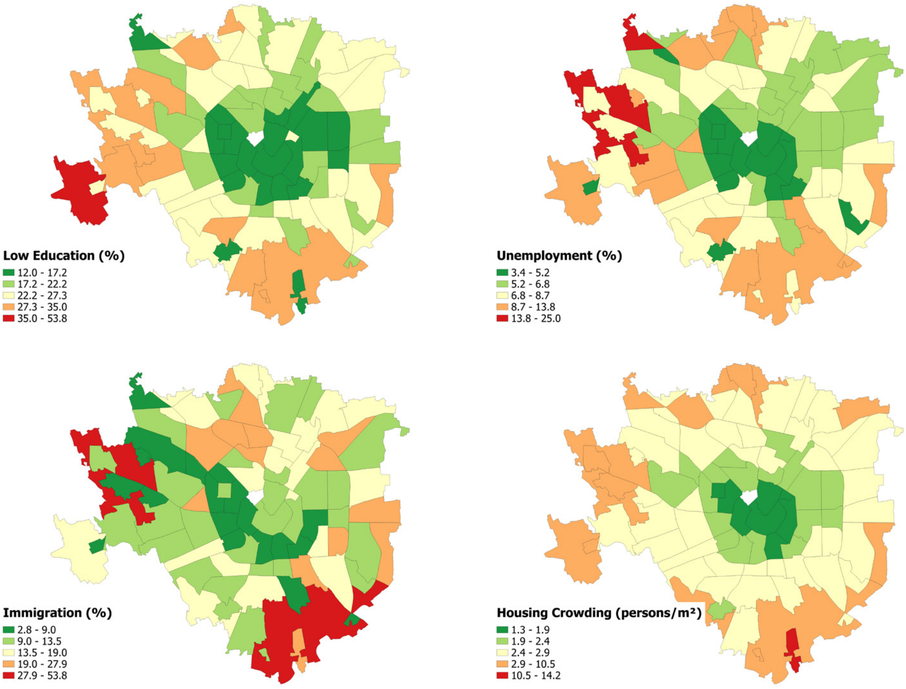

Figure1. Neighbourhood distribution of socioeconomic indicators.
Figura 1. Distribuzione degli indicatori socioeconomici per quartiere.

increasingly deprived peripheral areas.[51-53] However, when comparing the indicators, although they align with the overall centre-periphery pattern, there are variations in the configuration of the areas with the highest levels of disadvantage. This suggests the multidimensionality of socioeconomic deprivation, as supported by the very low to moderate correlations among the four indicators (ranging from 0.04 to 0.53; see Table S1 in the online Supplementary Materials).
Figure 2 illustrates the distribution of Bayesian Relative Risks (BRRs) for the health outcomes. For the same reason discussed above, quantile division was avoided to prevent emphasizing differences that are not actually present in the data. Each health outcome's BRRs were mapped on the city map, with equal intervals centred around the city average.[2] BRR values around 1 (in yellow) indicate prevalence or rates close to the overall city average, values above 1 (in red scale) indicate areas with higher adjusted prevalence or rates, and values below 1 (in green scale) indicate areas with lower prevalence or rates. The geographic distribution of health outcomes generally followed the pattern of the socioeconomic indicators, with some specificities and variations. In addition to the consistent distinction between central and peripheral areas, the western periphery displayed a cluster of neighbourhoods with higher concentrations of adverse health outcomes related to diabetes, respiratory diseases, metabolic syndrome, polypharmacy, and to a lesser extent, hypertension and multimorbidity. Increased mortality risks were observed in scattered peripheral areas throughout the city. However, a reverse territorial gradient was observed for neoplasms, and no specific spatial pattern was detected for antidepressant use. Similar results were obtained when plotting the Standardized Incidence Ratios (SIRs), as shown in Figure S2 (online Supplementary Materials), which encompasses also information on the absolute values of the numerators the indicators considered, as a way to indirectly assess the uncertainty around the estimates.
Table 2 displays the correlation coefficients (ρ) between the socioeconomic indicators and health outcomes. The rho coefficients range from -1, indicating a total negative correlation, to +1, indicating a total positive correlation, while 0 indicates no correlation. The 95% confidence intervals were obtained using bootstrap with 1,000 replicas to account for the uncertainty in the estimates. In interpreting the correlation coefficients, it is important to note that cut-off points for determining the strength of the association are often considered arbitrary. However, conventional approaches classify associations as very weak for absolute values of the coefficient between 0.0 and 0.19, weak for values 0.20-0.39, moderate for values 0.40-0.59, strong for values 0.60-0.79, and very strong for values 0.80-1.0.
Among the socioeconomic disadvantage indicators, low education showed the strongest correlations with the health outcomes. It was significantly associated

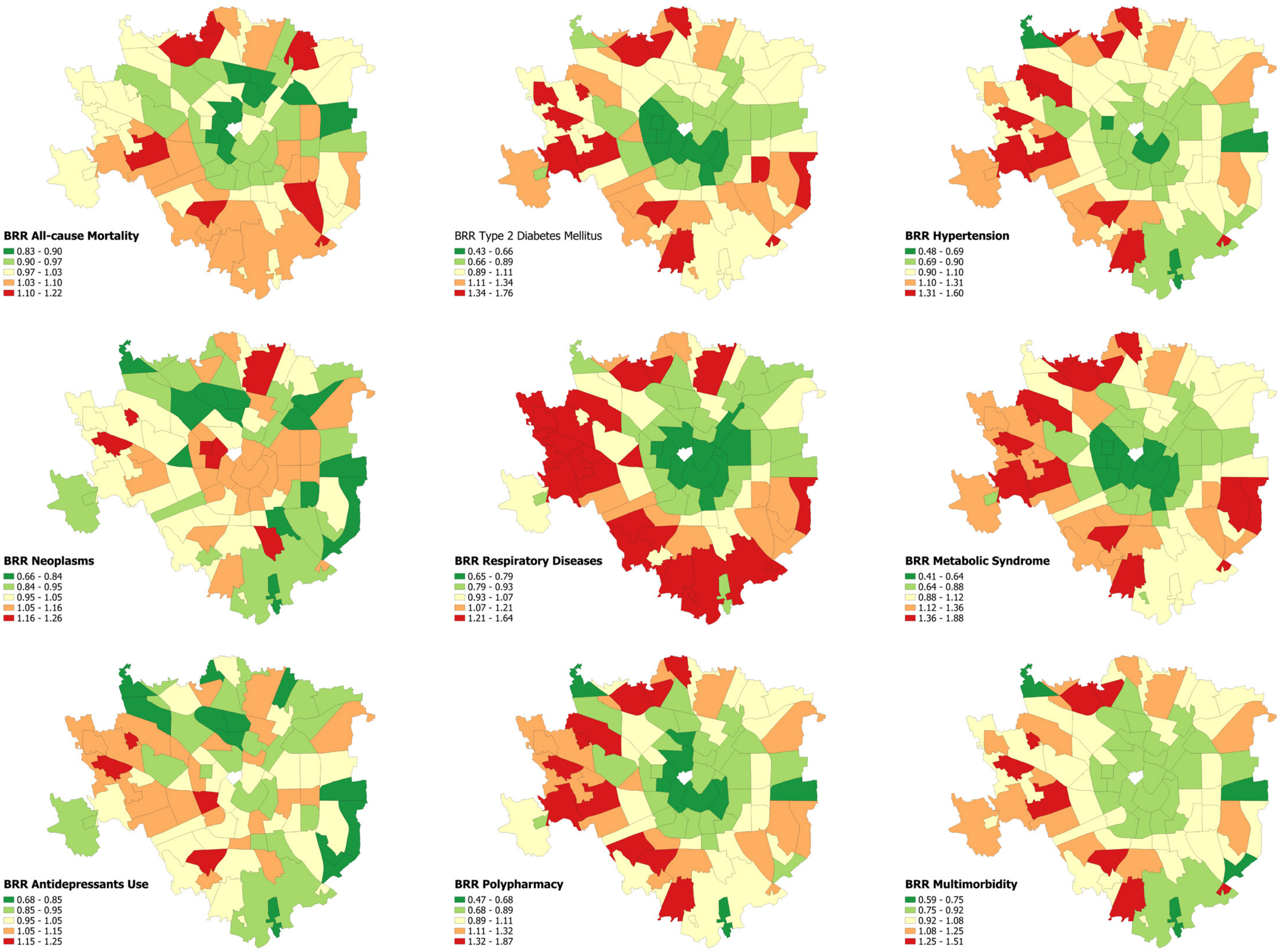

Figure 2. Bayesian Relative Risks (BRRs) of the health outcomes investigated, calculated using BYM2 method.
Figura 2. Rischi relativi bayesiani (BRR) riferiti agli esiti di salute indagati, calcolati utilizzando il metodo BYM2.

Adverse health outcomes	Socioeconomic disadvantage indicator							
	Low education		Unemployment		Immigration		Housing crowding	
	ρ	(IC95%)	ρ	(IC95%)	ρ	(IC95%)	ρ	(IC95%)
All-cause mortality	0.14	(-0.08;0.34)	0.24	(0.03;0.44)	0.03	(-0.19;0.24)	0.14	(-0.07;0.35)
Diabetes	0.77**	(0.66;0.85)	0.58**	(0.42;0.71)	0.36*	(0.16;0.54)	0.66**	(0.52;0.77)
Hypertension	0.75**	(0.64;0.83)	0.55**	(0.37;0.68)	0.10	(-0.12;0.31)	0.62**	(0.46;0.73)
Neoplasms	-0.36**	(-0.54;-0.16)	-0.39**	(-0.56;-0.19)	-0.55**	(-0.68;-0.38)	-0.45**	(-0.61;-0.26)
Respiratory diseases	0.73**	(0.60;0.81)	0.54**	(0.37;0.68)	0.24	(0.03;0.44)	0.51**	(0.33;0.65)
Metabolic syndrome	0.63**	(0.48;0.75)	0.53**	(0.35;0.67)	0.24	(0.03;0.44)	0.55**	(0.38;0.69)
Antidepressants use	-0.02	(-0.24;0.20)	-0.14	(-0.35;0.08)	-0.40**	(-0.57;-0.20)	-0.21	(-0.40;0.01)
Polypharmacy	0.70**	(0.56;0.79)	0.48**	(0.29;0.63)	0.12	(-0.10;0.33)	0.47**	(0.28;0.62)
Multimorbidity	0.72**	(0.60;0.81)	0.48**	(0.29;0.63)	0.07	(-0.15;0.28)	0.54**	(0.36;0.68)

* p-value ≤0.05   ** p-value ≤0.01

Table 2. Spearman rank correlation coefficient (ρ) and 95% confidence intervals between socioeconomic disadvantage and adverse health indicators.
Tabella 2. Coefficienti di correlazione di Spearman (ρ) tra svantaggio socioeconomico ed esiti di salute avversa, con relativi intervalli di confidenza al 95%.

with diabetes (ρ: 0.77), hypertension (0.75), multimorbidity (0.73), respiratory diseases (0.73), polypharmacy (0.70), and metabolic syndrome (0.63). Unemployment and housing crowding also exhibited positive correlations, although to a lesser extent, with these health conditions. A common trend observed across all socioeconomic indicators was a moderate inverse correlation with neoplasms and antidepressant use, although the statistical significance varied. Weak correlations were found between all-cause mortality and all socioeconomic measures, except for immigration, which showed a weak correlation only with diabetes.

Discussion

The objective of this study was to conduct a systematic analysis of health inequalities in the city of Milan using an ecological approach. By combining administrative healthcare data and socioeconomic data from official statistics, the study aimed to investigate the relationship between aggregate measures of socioeconomic disadvantage and population health outcomes, using a diverse set of variables. The findings revealed that, to varying degrees, all the health outcomes examined were significantly associated with socioeconomic disadvantage. These results are consistent with recent national ecological studies conducted in Turin[54] and Bologna[55], which also followed the 'Social Determinants of Health' approach and focused on a wide range of health outcomes in Northern Italy. While the association between area-level socioeconomic indicators and health outcomes is well established in the literature, and the presence of both social and territorial gradients in health in Milan has been previously demonstrated,[51] it is still valuable to explore the context-specific patterns related to different health conditions, as they may exhibit unique trajectories. This study contributes to the existing body of knowledge by systematically describing and analysing health inequalities in Milan, shedding light on the association between socioeconomic disadvantage and population health outcomes across various variables.

Indeed, the analysis provides strong evidence of the association among non-communicable diseases, such as diabetes, hypertension, respiratory diseases, metabolic syndrome, polypharmacy, and multimorbidity, and three of the four socioeconomic indicators. Among these indicators, low education exhibits the strongest correlations. These findings align with existing literature that identifies education as the most influential social determinant of health.[56] Education plays a crucial role in shaping health behaviours through its association with health literacy. Additionally, education indirectly impacts health status through its influence on occupational class and income levels, which in turn affect various mechanisms related to health.[4,57] As a measure at the area-level, low education could capture the aggregation of individuals with low socioeconomic status who may have a higher exposure to health-related risk factors (compositional explanation). Additionally, the concentration of disadvantaged individuals in certain areas may contribute to the identification of less attractive areas with limited access to health resources, thereby influencing health outcomes regardless of individual characteristics (contextual effect). However, since this study lacks individual-level data and does not model individual and contextual effects at the appropriate level of analysis, these remain speculative interpretations. It is important to highlight that, if the concentration of non-communicable diseases aligns with the socioeconomic structure of the urban area, it has significant implications for policy interventions aimed at addressing health inequalities and reducing the burden of chronic diseases based on the underlying territorial arrangement. If the predominance of the compositional explanation is observed, interventions should focus on improving individual socioeconomic conditions in less affluent areas, regardless of the physical and social characteristics of the urban environment. This may involve initiatives such as enhancing health literacy to promote healthy behaviours and implementing primary and secondary prevention strategies. Redistributive interventions aimed at reducing socioeconomic disparities can play a crucial role in improving health outcomes. On the contrary, if neighbourhood effects are found to play a significant role in shaping disease outcomes, policy actions should go beyond addressing individual socioeconomic conditions. In addition to improving individual circumstances, interventions should also directly target structural factors that influence healthy lifestyles in less equipped areas. These may include initiatives to enhance walkability, increase access to green spaces and improve food environments. While this study may not have fully addressed the issue of compositional and contextual effects, the results obtained can guide further research and help identify priority areas for intervention. Complementary methodologies, such as qualitative in-depth analyses, can be employed to gain a deeper understanding of the underlying processes and mechanisms driving the observed patterns of inequality. Recent research conducted in Bologna, for example, has successfully employed qualitative approaches to complement quantitative findings and provide a more comprehensive understanding of health inequalities.[58]

A systematic inverse relationship was observed in the case of neoplasms, which aligns with previous knowledge indicating a reverse social gradient in neoplasms among women.[59] Moreover, compared to other non-communicable diseases, social inequalities in neoplasms among men are generally less pro-

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nounced,[60,61] except for smoking-related cancers in Italy.[62] Similar findings have been reported in previous studies conducted in Milan, supporting the existence of a reverse social gradient in neoplasms.[63] Although the negative association was statistically significant only for two of the four investigated socioeconomic predictors, a similar inverse relationship was also observed in relation to antidepressant use. This finding is consistent with previous research that has shown contrasting results, suggesting a potential unmet need for treatment among the less privileged.[64]

From the analysis conducted, it is evident that the city of Milan exhibits distinct patterns of geographical heterogeneity in the health conditions investigated, which are variably associated with the considered socioeconomic predictors. This spatial patterning is not discernible from the global analysis performed using Spearman's coefficients, but rather from a detailed inspection of the descriptive maps illustrating the territorial distribution of health outcomes. For instance, it is possible to notice some areas that do not exhibit significant levels of socioeconomic disadvantage, but have high-risk classes for all observed outcomes, and vice-versa. Obviously, this is due to the fact that the area socioeconomic status is neither the only nor the most important factor involved in the process leading to the onset of one or more medical conditions. Although adjusting the prevalences for age and sex may have mitigated compositional effects to some extent, it is clear that the association between health outcomes and area-level socioeconomic disadvantage is contingent and partial. This is because health outcomes are plausibly influenced by other factors at both the contextual (e.g., air and noise pollution, service accessibility, walkability/cyclability, perceived safety, nutritional environment) and individual (e.g., health-related behaviours and lifestyles, stress exposure, working environment) levels, which were not considered in this study. The study aimed to assess the association at an aggregate level as an initial approach to exploring the influence of area socioeconomic characteristics on disease outcomes.

Limitations of the study

As for limitations, it is important to note that the results of this study should be interpreted with caution to avoid the ecological fallacy.[65] While the variables used in the analysis were derived from individual-level data, the relationships observed should not be directly interpreted as individual-level associations. To properly disentangle the effects of composition and context on health outcomes, multilevel models with individuals nested within neighbourhoods would be the ideal approach.[66] However, in this study, an ecological analysis was conducted due to the lack of detailed information on individual socioeconomic characteristics. It is important to acknowledge this limitation and recognize that individual-level factors and contextual factors may interact in complex ways that cannot be fully captured by the aggregate-level analysis employed in this study. An alternative approach that could be considered is using small-area socioeconomic information, such as data from census blocks, as a proxy for individual socioeconomic position. However, it is important to acknowledge that this approach is not without its limitations and potential biases.[67,68] Another limitation of this study is the considerable time lag between the socioeconomic indicators (based on data from 2011) and the health outcomes (based on data from 2019). Over time, various demographic, migration, gentrification, requalification, and urbanization processes may have occurred, potentially altering the socioeconomic composition of local areas within the city. Therefore, using non-up-to-date territorial data may not accurately reflect the current socioeconomic organization of the urban space. It is important to consider this time discrepancy when interpreting the findings and recognize that the associations observed may be influenced by changes that have taken place between the two time points. However, several studies have demonstrated that the structural relationships among local areas within an urban environment tend to remain relatively stable over time, even in the presence of significant socioeconomic events or changes.[69-71] This suggests that it is possible to conduct analyses using past census data, as long as the temporal lag between the data and the outcomes being studied is not too large. Finally, it is important to acknowledge that health outcomes occurring at a specific point in time, such as disease onset or death, are influenced by factors accumulated throughout a person's life. The context of residence during a particular period may not fully capture the exposure to risk factors that occurred in the past. For example, the neighbourhood of residence during youth may have a stronger influence on disease outcomes than the context where the adverse health condition manifested in adulthood, particularly in cases of residential mobility. However, due to the lack of longitudinal data, it is not possible to account for these temporal dynamics in the current analysis. Nevertheless, from the perspective of an ecological analysis aimed at mapping disease distribution and inequality to inform public health interventions, it may be less relevant to determine where the risk factors originated and more important to identify areas with a higher concentration of adverse health outcomes and socioeconomic inequality. These are the areas that warrant targeted interventions and resources to address the challenges they face.

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Conclusions

This ecological study aimed to investigate health inequalities in the city of Milan by examining a comprehensive range of indicators, combining administrative healthcare data with socioeconomic information from the national census. The consistent association between socioeconomic measures and health outcomes, regardless of the specific indicators used, provided robust evidence of territorial variations in health conditions in Milan. These patterns were not likely to be due to chance, as they consistently emerged across different areas. Peripheral neighbourhoods in Milan exhibited a concentration of both socioeconomically disadvantaged individuals and those affected by single or multiple chronic diseases. These findings highlight the importance of identifying and addressing these areas through targeted public health initiatives. By considering individual and contextual socioeconomic factors, efforts can be made to reduce disparities and improve overall health conditions. However, further research is needed to better understand the relative impact of individual and neighbourhood characteristics and to uncover the underlying mechanisms driving these patterns of inequality.

Conflicts of interest: none declared.

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