Original article

# Regional indices of socio-economic and health inequalities: a tool for public health programming

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Keywords

Public health • Socio-economic status • Socio-economic indices • Inequalities in health • Health care resources

Summary

**Objectives**. *The aim was to provide an affordable method of computing socio-economic (SE) deprivation indices at the regional level, in order to reveal the specific aspects of the relationship between SE inequalities and health outcomes. The Umbria Region Socio-Health Index (USHI) was computed and compared with the Italian National Deprivation Index at the Umbria regional level (NDI-U).*

**Methods**. *The USHI was computed by applying factor analysis to census tract SE variables correlated with general mortality and validated through comparison with the NDI-U.*

**Results**. *Overall mortality presented linear positive trends in USHI, while trends in NDI-U proved non-linear or non-significant. Similar results were obtained with regard to specific causes of death according to deprivation groups, gender and age.*

**Conclusions**. *The USHI better describes a local population in terms of health-related SE status. Policy-makers could therefore adopt this method in order to obtain a better picture of SE-associated health conditions in regional populations and to target strategies for reducing health inequalities.*

## Introduction

Over the last fifty years, most countries have investigated the relationships between socio-economic (SE) status and inequalities in the utilisation and distribution of healthcare resources and patient outcomes [1-6]. These studies have been carried out at the national or individual level, and have examined the relationships between the distribution of demographic characteristics (gender and age), SE factors (income and occupation), cultural factors (educational level), living conditions (marital status, household composition, domestic overcrowding and tenure, etc.) and health outcomes in areas ranging from the macro to the micro level [5, 6]. Indeed, an SE classification that takes the patient's neighbourhood into account provides a useful starting point in describing and improving the effectiveness of local public health interventions [4, 6].

The definition of "neighbourhood" is debated in the literature, the most common being that of the smallest official administrative area [5-9], usually the census tract (CT), which approximates the SE and health features of the area to the resident individuals' characteristics.

This choice is justified by the aim of such studies, which is to accurately assess the feasibility of providing preventive, diagnostic and therapeutic services targeted to individuals who live in a specific area.

Most of these studies have utilised indices of SE deprivation that were computed for the whole nation [6, 7]. Moreover, it is noteworthy that such indices were commonly constructed in order to describe the distribution of the population with respect to SE characteristics, but not to show the specific effects of SE deprivation on deprivation-related health outcomes.

This methodological choice raises some critical problems. Firstly, these indices are often not sufficiently related to overall mortality, the main and most commonly used health indicator. Worldwide, overall mortality is related to material and social differences in the population and to inequalities in the distribution of public and private health resources [10]. Computed according to this "pure" definition of SE deprivation, the usual deprivation indices do not consider whether their constituent variables influence health status [6, 7]. They therefore risk neglecting to evaluate differences in the local allocation of resources in response to health needs. These differences can be particularly marked in countries with large differences in national and regional demographics and SE status, causing considerable disparities in health outcomes [5].

Significant examples of such situations can be found in Italy, a country where population density varies from region to region, ranging from 39 to 429 inhabitants per square km. Moreover, the various regions differ in terms of the rate of population ageing, proportion of the population that is active, birth rate, family size, and labour market characteristics, particularly from North to South [11]. In addition, the orographic characteristics of the territory in the various regions impacts on the internal distribution of goods and wealth. In brief, the economy of Northern Italy is similar to, and connected with, that of Central Europe, while the Central and Southern


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regions of Italy are penalised by their poor connection with the heart of Europe.
It is also necessary to consider how public financing is distributed. With few exceptions, funds flow from the central government to the single regional authorities, which decide how they should be allocated and determine the amount and distribution of resources devoted to socio-health policies (social support, preventive measures, etc.) [11-14].
In countries with such characteristics, all these aspects lead to health inequalities that are specific to each region, and particularly to sub-areas where population density is lower [5]. These inequalities can be accurately described and analysed only by means of indicators that are constructed at the regional level and which can take local peculiarities into account [5-7]. Such indicators are computed on the basis of health-related local demographic and SE indicators [9, 12]. These indices should be called Indices of SE and Health Inequalities (SHI), rather than Deprivation Indices, as they describe the population distribution not only in terms of mere SE inequalities, but also according to people's needs for health support.
The present study aimed to describe, discuss and validate the method and the technique for computing this kind of index, which could be applied in every nation affected by marked regional differences. The Umbria region was chosen as an example of the application of these procedures, which are derived from a previous successful attempt in another Italian region (Liguria) [8, 9, 12]. Moreover, this study assessed the ability of the Umbria regional index (USHI) to efficiently classify population subgroups in Umbria on the basis of a combination of health fragility and SE differences related to health outcomes, in comparison with the Italian National Deprivation Index (NDI) computed at the level of the Umbria region (NDI-U), which distinguishes populations only on the basis of SE status [7-9, 12].

## Methods

The NDI is the benchmark for validating local indices (USHI in this study). As the NDI based on the 2011 National Census data is not yet available, we used local SE and mortality data from around 2001 (the date of the latest available NDI) in order to compute the local index (USHI), and mortality data from the period 2005-2012 to analyse the performance of the two indices.
We used 543 variables taken from the 2001 Italian Census in order to compute the two indices at the CT level; these variables describe features of individuals (age, marital status, educational level, employment, etc.), families (number of family members, single parents, average age of families, etc.) and households (ownership, over-crowding, housing conditions, services available, etc.).
The NDI considered 280 of these variables, covering five conditions which described the multidimensional concept of social and material deprivation (persons with only primary education, unemployed or searching for first employment, one-parent families and dependent children living together, rented accommodation, domestic overcrowding) [7]. The NDI was computed at the CT level as the sum of these five indicators in standardised form, grouped in population quintiles at the national level [7]. In the present study, we used a regional version of the NDI (NDI-U), categorised in quintiles of the Umbrian population.
To construct the USHI, we adopted the same method used to compute the Liguria Socio-economic and Health Inequalities Index (LSHI) [8]. Pearson's bivariate correlation ($p < 0.05$) was calculated between each of the 543 basic variables and the synthetic SE indices (employment/unemployment rates, ageing index, dependence rate, etc.) and general mortality in Umbria in 2001-2004. Significantly correlated variables were picked out and a tolerance test ($p < 0.05$) was applied to these in order to reduce collinearity [15]. From the nine variables which emerged after these steps, a principal-component analysis extracted three factors. These defined the latent structure connecting the SE variables that were able to synthetically describe the health-related SE characteristics of the population. The three factors underwent a varimax rotation, in order to render them orthogonal, and thus independent. These three independent factors were linearly combined into a single quantitative variable, the values of which were re-scaled as a percentage in order to obtain the USHI at the CT level [16] (Tab. I). Subsequently this variable was aggregated, both for the purpose of its validation and to obtain a municipality index, based on the CTs in each municipality (Tab. SI). This operation was necessary because the population of the Umbria region is small (825,796 inhabitants); therefore, a higher level of aggregation (municipality) than the CT was required in order to analyse the effects of deprivation on mortality according to the causes of death. The population of the largest municipalities (above 55,000 residents) were split into districts, on the basis of CT proximity, in order to create geographic areas with populations similar in size to those of other municipalities in the region.

**Tab. I.** Composition of the factors making up the USHI.

| Total explained variance = 71.0% | | |
|---|---|---|
| Factor 1= 30.7% | Factor 2= 23.0% | Factor 3 = 18.3% |
| % of owned houses | Youth employment rate | % of singles |
| % of houses with independent heating system | % of high school diplomas and university degrees | Employment rate |
| Number of persons in the family | Average age of 3-person families | |
| | % of people born in the municipality of residence | |

Finally, in order to obtain a normal distribution of the population across the deprivation clusters in the final USHI classification [9, 17], a cluster discriminant analysis, based on the algorithm of Agnelli et al. [17], was applied on aggregating municipalities and districts. The level of normalization was tested at $p < 0.05$ statistical significance.
The Umbria Regional Mortality Registry was the source of the 5-year general mortality (2001-2004) data used in selecting the variables pertaining to the USHI. The same Registry also provided the data on cause-specific mortality by age-group and gender (2005-2012), which were utilised to validate the USHI and compare its performances with those of the NDI-U.
The mortality features included in the present study were: the overall mortality rate (ICD-10$^{th}$: A00-Y89) and the rates of mortality due to diabetes mellitus (E10-E14), circulatory system (I00-I99), respiratory (J00-J99) and digestive (K00-K93) diseases in the period 2005-2012, by age-group (all ages, 0-64 and 65+ years old) and gender.
The Standard Mortality Ratio (SMR) of each group identified by the USHI and the NDI-U was computed against the overall regional rate, by age-group, gender and cause.
SMR variance was analysed with regard to the specific causes of death, in order to detect linear (L) or non-linear (NL) significant relationships with the deprivation groups. Significance was tested by means of the F-test ($p < 0.05$). Analyses were performed by means of SPSS 19.0 and Stata 12.0 statistical packages.

## Results

Table II displays the size of the Umbrian population and the percentages of this population in each group identified by the NDI-U and USHI; it also shows trend comparisons of some synthetic SE indices (replacement, age, structural dependence, activity, employment and unemployment). The groups were labelled from 1 to 5, on the basis of decreasing SE deprivation according to the NDI-U and decreasing socio-health-economic (SHE) deprivation according to the USHI (i.e., 1 = most deprived; 5 = least deprived).
Each of the five NDI-U deprivation groups comprised approximately one-fifth of the Umbrian population, according to the NDI computing techniques. The small differences from perfect quintiles were due to the sizes of the CT populations (obviously, the CTs cannot be divided).
In each USHI deprivation group, the population size was normally distributed, being larger in the central groups and smaller in the tails.
With respect to USHI distribution, all synthetic indices showed linear (L) trends that were consistent with SHE deprivation. Positive L trends (↑, increasing on increasing deprivation) were seen with regard to replacement, ageing, structural and unemployment indices, while

**Tab. II.** Population size and percentage of total population (825,796 inhabitants) of SE deprivation groups identified by the NDI-U and USHI. Comparison of trends between distributions of some synthetic SES indices (ISTAT) in the NDI-U and USHI population groups.

| SE deprivation groups | | 1 | 2 | 3 | 4 | 5 | Trend |
|---|---|---|---|---|---|---|---|
| NDI-U | N° of residents (%) | 156,473 (19.0%) | 175,700 (21.3%) | 176,965 (21.4%) | 157,574 (19.1%) | 159,084 (19.3%) | |
| | Replacement Index | 147.3 | 132.4 | 141.8 | 150.2 | 151.5 | n.s. |
| | Ageing Index | 246.7 | 198.9 | 203.4 | 209.2 | 229.5 | n.s. |
| | Structural dependence Index | 59.2 | 57.7 | 58.1 | 57.9 | 61.4 | n.s. |
| | Activity Index | 63.8 | 64.9 | 64.6 | 64.3 | 64.0 | n.s. |
| | Employment index | 57.6 | 59.0 | 58.2 | 57.7 | 57.1 | n.s. |
| | Unemployment index | 9.2 | 8.4 | 9.3 | 9.7 | 10.2 | $p < 0.05$ NL |
| **SHE deprivation groups** | | **1** | **2** | **3** | **4** | **5** | **Trend** |
| USHI | N° of residents (%) | 162,196 (19.6%) | 176,275 (21.3%) | 188,458 (22.8%) | 163,401 (19.8%) | 135,466 (16.4%) | |
| | Replacement Index | 177.4 | 149.7 | 139.5 | 132.9 | 127.9 | $p < 0.05$ L↑ |
| | Ageing Index | 332.2 | 217.3 | 209.6 | 182.4 | 168.6 | $p < 0.05$ L↑ |
| | Structural dependence Index | 68.0 | 59.8 | 58.8 | 54.8 | 53.5 | $p < 0.05$ L↑ |
| | Activity Index | 61.4 | 62.8 | 63.9 | 66.2 | 67.4 | $p < 0.05$ L↓ |
| | Employment index | 54.5 | 55.9 | 57.6 | 59.8 | 61.9 | $p < 0.05$ L↓ |
| | Unemployment index | 10.7 | 10.4 | 9.3 | 9.0 | 7.6 | $p < 0.05$ L↑ |

SE group labels indicate decreasing SE deprivation from 1 = most deprived to 5 = least deprived; SHE group labels indicate decreasing SHE deprivation from 1 = most deprived to 5 = least deprived. L = linear trend; NL = non-linear trend; n.s. = non-significant trend; ↑ = positive trend (increasing with deprivation); ↓ = negative trend (decreasing with deprivation).

activity and employment indices displayed negative L trends (↓, decreasing on increasing deprivation).
In the NDI-U, no significant (NS) correlation was found, except for the unemployment index, which showed a NL relationship.
USHI overall mortality trends (Tab. III) showed L↑ trends in males and females, while NDI-U trends were NL in men and NS in women. Concerning age, the USHI trend was L↑ in the younger age-groups and in older females, but NL in older males. NDI-U age-related trends were NL among males in both age-groups and NS among females.
The distribution of the main causes of death, by SE (NDI-U) and SHE (USHI) groups, is shown in Table IV. The USHI trends in diabetes-related deaths were L↑ in women and NL in men, while the NDI-U trends were NS. By age-group, the USHI trends were L↑ only in the elderly, being NS in the young. The NDI-U trends were NS in males in both age-groups, and NL in younger women.
Regarding circulatory system diseases, USHI trends were L↓ in men and NL in women, While NDI-U trends were NL in men and NS in women. Concerning age-groups, USHI trends were L↑ in younger men, L↓ in older men and NL in both female age-groups. NDI-U displayed NL trends in males and NS in females.
Respiratory system diseases showed NL USHI trends in both sexes, while NDI-U trends were NS. Age-related USHI trends were NL in both groups of men and NS in younger women. All the age-related NDI-U trends were NS.
Finally, with regard to diseases of the digestive system, USHI trends were L↑, while NDI-U trends were NS in men and NL in women. When linked to age, USHI trends were L↑ in younger men and older women, NL in older men and NS in younger women. NDI-U trends were NL in older subjects and NS in the younger groups.

## Discussion

Tables II and III show very marked differences between the two indices in terms of their relationships with the synthetic SE indicators (Tab. II) and the distribution of overall mortality across the SE groups of population (Tab. III). The NDI-U displayed only a weak correlation with mortality (the health indicator), confirming the findings at the national level [7]; moreover, correlations with the SE indicators were either non-significant or non-linear. These results confirmed those of other studies, particularly the Liguria study [12] and a national one, involving 10 other Italian regions [18, 19].
The NDI is a commonly accepted benchmark at the national level. However, if the same procedures are applied at the local level in order to obtain a local version of this index, and if the same variables and population seg-

**Tab. III.** 2005-2012 ove rall mortality in Umbria by gender, age and deprivation groups identified by NDI-U and USHI: Standard Mortality Ratios (SMR), cases and trend significance.

| Indexes | Age groups | Indi-cator | MEN | | | | | | | WOMEN | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Umbria | Trend | 1 | 2 | 3 | 4 | 5 | Umbria | Trend |
| **NDI-U** | All ages | SMR | 97.9 | 96.7 | 98.0 | 103.4 | 99.9 | 99.1 | P <0.05 NL | 99.6 | 96.5 | 97.8 | 101.1 | 100.5 | 99.0 | n.s. |
| | | OBS | 7245 | 8389 | 7919 | 7446 | 7764 | 38763 | | 7685 | 8445 | 8202 | 7620 | 7941 | 39893 | |
| | 0-64 yrs | SMR | 95.0 | 95.5 | 98.1 | 102.2 | 104.6 | 99.0 | P < 0.05 NL | 103.7 | 90.7 | 100.2 | 98.5 | 99.9 | 98.5 | n.s. |
| | | OBS | 968 | 1082 | 1129 | 1088 | 1033 | 5300 | | 590 | 566 | 649 | 579 | 543 | 2927 | |
| | 65+ yrs | SMR | 98.3 | 96.8 | 98.0 | 103.7 | 99.2 | 99.1 | P < 0.05 NL | 99.3 | 96.9 | 97.5 | 101.4 | 100.5 | 99.1 | n.s. |
| | | OBS | 6277 | 7307 | 6790 | 6358 | 6731 | 33463 | | 7095 | 7879 | 7553 | 7041 | 7398 | 36966 | |
| **USHI** | All ages | SMR | 102.7 | 101.9 | 99.8 | 99.1 | 98.7 | 99.1 | P < 0.05 L↑ | 103.1 | 101.7 | 99.6 | 99.5 | 97.6 | 99.0 | P < 0.05 L↑ |
| | | OBS | 7998 | 9011 | 8386 | 7244 | 6124 | 38763 | | 8669 | 9359 | 8680 | 7364 | 5821 | 39893 | |
| | 0-64 yrs | SMR | 108.8 | 105.4 | 96.6 | 95.0 | 95.6 | 99.0 | P < 0.05 L↑ | 105.7 | 100.5 | 93.7 | 94.7 | 93.0 | 99.5 | P < 0.05 L↑ |
| | | OBS | 1062 | 1195 | 1143 | 1013 | 887 | 5300 | | 641 | 623 | 618 | 551 | 494 | 2927 | |
| | 65+ yrs | SMR | 99.4 | 101.4 | 94.9 | 99.8 | 100.4 | 99.1 | P < 0.05 NL | 101.3 | 101.8 | 99.9 | 99.9 | 97.6 | 99.1 | P < 0.05 L↑ |
| | | OBS | 6936 | 7816 | 7243 | 6231 | 5237 | 33463 | | 8028 | 8736 | 8062 | 6813 | 5327 | 36966 | |

SE group labels indicate decreasing SE deprivation from 1 = most deprived to 5 = least deprived; SHE group labels indicate decreasing SHE deprivation from 1 = most deprived to 5 = least deprived. L = linear trend; NL = non-linear trend; n.s. = non-significant trend; ↑ = positive trend (increasing from 1 to 5 group); ↓ = negative trend (decreasing from 1 to 5 group).

mentation (quintiles) are used, its ability to distinguish population groups in terms of SE and health differences seems to be weakened.

Although the NDI-U groups were formed by quintiles, SE phenomena more frequently display a normal distribution (as do many other phenomena: e.g., many health-related indicators) [20, 21]. Thus, the USHI was constructed in accordance with a normal distribution of the population in clusters, in order to maximise the probability of relationships with SE characteristics. The validity and reliability of this methodological choice are demonstrated by the linear correlations that the synthetic SE indicators (replacement, ageing, dependence rate, activity, and employment) showed (linear correlations in USHI, but not in NDI-U).

Furthermore, only USHI trends in overall mortality almost always confirmed other reports [1-4, 22]. USHI age-trends illustrated the effects of inequalities on overall mortality, revealing that SMRs increased with SHE deprivation in both female age-groups and in younger males. The NDI-U failed to draw out this information or to identify the well-known relationship between SE deprivation and the major causes of death explored in this study (Tab. IV).

USHI trends depicted female-related advantages (e.g., greater attention to prevention) and disadvantages (e.g., greater ageing and disability) [23-25], suggesting a strong relationship with confounding factors in older men, such as deleterious habits and occupational risks.

Regarding specific causes of death (Tab. IV), the associations observed in the younger age-groups were interesting, in that the low frequency of competitive diseases made it easier to identify determinants of risk, and also SE-linked factors. Indeed, younger age-groups tend to be more receptive to campaigns for the prevention and early diagnosis of diseases. Such campaigns facilitate a timely diagnosis and are associated with more efficacious treatments and better care and outcomes, though their effects may differ across SHE clusters [14, 23, 24]. Their effects may differ in the intensity of exposure to risk factors (such as occupational exposure in older men) or to differences in implementing preventive or diagnostic/therapeutic strategies. For instance, women are known to be more likely to display beneficial behavioural patterns, such as adopting healthy dietary habits and adhering to early prevention [23, 24]. However, this predisposition is mostly culturally mediated, being greater in the less deprived than in the more deprived [25].

With regard to the main diseases, the trends which emerged from the present study mainly confirmed the findings from other studies. The more lethal diseases, for which less efficacious preventive and therapeutic options are available, showed a more homogeneous distribution of mortality among the population clusters, because, although exposure to risk factors was not similar in all individuals, care opportunities were limited in the same way for all. Conversely, when preventive and therapeutic options are available, mortality rates differ among clusters of population at different SHE deprivation levels [12, 26, 27]. Specifically, the literature indicates that ageing-linked social challenges and poor healthcare are mediated by SE differences, and that they are worse in one-person families, particularly in the elderly [26, 27].

The growing prevalence of diabetes in populations with a western life-style [28-31] has shown robust positive associations with SE deprivation in both males and females [28]. The main risk factors, i.e. overweight or obesity and inheritance of the disease from parents, suggest a common environment or gene-environment interaction and SE deprivation. These factors, however, can be partially counterbalanced by better education and the adoption of a healthier lifestyle). Moreover, diabetes is reported to increase the individual's vulnerability to airborne particles emitted by the combustion of hydrocarbons, and an inverse relationship has emerged between air pollution and nitro-glycerin-mediated reactivity in older people [29, 30]. These detrimental effects might affect the population differentially across SHE groups, as suggested by the positive trends seen in elderly persons of both sexes in Umbria.

Cardiovascular diseases are associated with lifestyle (smoking, alcohol, metabolic disorders, scant physical activity, overweight and obesity, pollution exposure) in all SE groups [29-34]. In Italy, smoking has decreased among young males, although to a lesser extent in the most deprived [35]. Among Italian women, smoking started at a later date, but spread rapidly from the most privileged to the other SE groups [35]. As yet, there are only a few signs of a decline in female smokers [36]. Umbria has the third highest smoking prevalence in Italy [36], which might partially account for the very high differences in risks between younger and older men across SHE groups and the non-linear trend in women.

Health campaigns and corrective actions on diet [38, 39] have had an effect in Italy, but SE differences still penalise the most deprived. The association between unhealthy eating and low SE status seen in the most deprived population strata in Umbria could be linked to the consumption of a traditional diet, which is rich in red meat and processed meat, even in the less deprived population strata [40].

The association between air pollution, particularly that caused by ultrafine particles, and low SE condition [41, 42] impacts on cardiovascular diseases. These particles reach cardiovascular sites, cause systemic inflammation in response to oxidative stress and promote the progression of atherosclerosis. In Umbria, this association emerged in urban areas with an industrial background (i.e., the town of Terni), while rural areas of the region appeared to be less affected.

Most deaths caused by diseases of the respiratory system are due to chronic-obstructive pulmonary diseases [43, 44], which affect the deprived more than the other groups. Although smoking is one of the main causes, significant roles are attributed to occupational exposure and air pollution. The present findings in Umbria only partially confirmed the positive association observed elsewhere in deprived people [43-46]. Lifestyle differences (rural/urban) could be partly responsible for these differences. Moreover, we recorded a few deaths attrib-

**Tab. IV.** 2005-2012 mortality in Umbria, by cause, gender, age and deprivation groups identified by NDI-U and USHI: Standard Mortality Ratios (SMR), cases and trend significance.

| CAUSE | INDICES | AGE GROUPS | INDICATOR | MEN | | | | | | | WOMEN | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | Umbria | Trend | 1 | 2 | 3 | 4 | 5 | Umbria | Trend |
| DIABETES | NDI-U | All ages | SMR | 100.0 | 99.1 | 102.2 | 89.8 | 105.7 | 99.5 | n.s. | 100.4 | 93.8 | 98.0 | 106.7 | 98.8 | 99.3 | n.s. |
| | | | OBS | 140 | 163 | 156 | 122 | 156 | 737 | | 194 | 206 | 205 | 200 | 196 | 1001 | |
| | | 0-64 yrs | SMR | 130.2 | 75.7 | 121.5 | 93.3 | 79.7 | 100.0 | n.s. | 116.7 | 70.5 | 51.4 | 207.9 | 60.6 | 100.4 | p < 0.05 NL |
| | | | OBS | 20 | 13 | 21 | 15 | 12 | 81 | | 6 | 4 | 3 | 11 | 3 | 27 | |
| | | 65+ yrs | SMR | 96.3 | 101.8 | 99.8 | 89.4 | 108.7 | 99.5 | n.s. | 100.0 | 94.4 | 99.3 | 103.7 | 99.7 | 99.3 | n.s. |
| | | | OBS | 120 | 150 | 135 | 107 | 144 | 656 | | 188 | 202 | 202 | 189 | 193 | 974 | |
| | USHI | All ages | SMR | 109.3 | 125.8 | 89.9 | 70.3 | 77.4 | 99.5 | p < 0.05 NL | 117.1 | 101.5 | 90.4 | 81.3 | 86.0 | 99.3 | p < 0.05 L↑ |
| | | | OBS | 166 | 211 | 150 | 97 | 113 | 737 | | 255 | 235 | 204 | 150 | 157 | 1001 | |
| | | 0-64 yrs | SMR | 99.9 | 121.3 | 106.6 | 75.3 | 93.7 | 100.0 | n.s. | 143.9 | 123.5 | 50.7 | 57.6 | 132.5 | 100.4 | n.s. |
| | | | OBS | 16 | 21 | 19 | 12 | 13 | 81 | | 8 | 7 | 3 | 3 | 6 | 27 | |
| | | 65+ yrs | SMR | 110.4 | 126.3 | 87.9 | 69.6 | 68.9 | 99.5 | p < 0.05 L↑ | 116.4 | 100.9 | 91.4 | 82.0 | 105.2 | 99.3 | p < 0.05 L↑ |
| | | | OBS | 150 | 190 | 131 | 85 | 100 | 656 | | 247 | 228 | 201 | 147 | 151 | 974 | |
| CIRCULATORY SYSTEM DISEASES | NDI-U | All ages | SMR | 97.3 | 98.2 | 98.4 | 102.8 | 98.7 | 99.0 | p < 0.05 NL | 99.8 | 96.8 | 96.0 | 101.4 | 101.1 | 98.9 | n.s. |
| | | | OBS | 2683 | 3197 | 2949 | 2734 | 2874 | 14437 | | 3488 | 3844 | 3634 | 3443 | 3626 | 18035 | |
| | | 0-64 yrs | SMR | 99.3 | 100.2 | 104.0 | 91.6 | 100.2 | 99.1 | p < 0.05 NL | 94.5 | 97.4 | 102.1 | 92.6 | 111.4 | 99.5 | n.s. |
| | | | OBS | 240 | 270 | 283 | 232 | 236 | 1261 | | 75 | 85 | 92 | 76 | 85 | 413 | |
| | | 65+ yrs | SMR | 97.1 | 98.0 | 97.9 | 104.0 | 98.6 | 99.0 | p < 0.05 NL | 99.9 | 96.8 | 95.8 | 101.6 | 100.9 | 98.9 | n.s. |
| | | | OBS | 2443 | 2927 | 2666 | 2502 | 2638 | 13176 | | 2070 | 3967 | 4677 | 4535 | 2373 | 17622 | |
| | USHI | All ages | SMR | 97.8 | 99.4 | 95.6 | 100.4 | 103.4 | 99.0 | p < 0.05 L↓ | 99.6 | 100.6 | 93.7 | 99.7 | 102.4 | 98.9 | p < 0.05 NL |
| | | | OBS | 2951 | 3303 | 3143 | 2711 | 2329 | 14437 | | 3951 | 4225 | 3834 | 3309 | 2716 | 18035 | |
| | | 0-64 yrs | SMR | 101.9 | 105.9 | 101.2 | 89.5 | 95.9 | 99.1 | p < 0.05 L↑ | 108.4 | 108.0 | 90.3 | 84.3 | 107.7 | 99.5 | p < 0.05 NL |
| | | | OBS | 254 | 287 | 284 | 226 | 210 | 1261 | | 93 | 94 | 83 | 68 | 75 | 413 | |
| | | 65+ yrs | SMR | 97.5 | 98.8 | 95.1 | 101.5 | 104.2 | 99.0 | p < 0.05 L↓ | 99.4 | 100.4 | 93.8 | 100.0 | 102.3 | 98.9 | p < 0.05 NL |
| | | | OBS | 2697 | 3016 | 2859 | 2485 | 2119 | 13176 | | 3858 | 4131 | 3751 | 3241 | 2641 | 17622 | |
| RESPIRATORY DISEASES | NDI-U | All ages | SMR | 103.5 | 92.7 | 89.5 | 107.9 | 103.3 | 98.9 | n.s. | 122.9 | 108.1 | 94.2 | 104.6 | 107.0 | 106.9 | n.s. |
| | | | OBS | 707 | 751 | 662 | 704 | 748 | 3572 | | 588 | 501 | 536 | 517 | 571 | 2713 | |
| | | 0-64 yrs | SMR | 125.9 | 65.1 | 67.4 | 120.2 | 125.6 | 99.3 | n.s. | 94.0 | 91.6 | 117.5 | 103.8 | 90.9 | 100.0 | n.s. |
| | | | OBS | 33 | 19 | 20 | 33 | 32 | 137 | | 14 | 15 | 20 | 16 | 13 | 78 | |
| | | 65+ yrs | SMR | 102.6 | 93.7 | 90.4 | 107.3 | 102.4 | 98.9 | n.s. | 123.8 | 108.7 | 93.4 | 104.7 | 107.4 | 107.1 | n.s. |
| | | | OBS | 674 | 732 | 642 | 671 | 716 | 3435 | | 574 | 486 | 516 | 501 | 558 | 2635 | |
| | USHI | All ages | SMR | 96.5 | 103.7 | 89.8 | 101.0 | 106.1 | 98.9 | p < 0.05 NL | 105.3 | 123.6 | 102.0 | 95.7 | 109.2 | 102.9 | p < 0.05 NL |
| | | | OBS | 721 | 858 | 733 | 672 | 588 | 3572 | | 619 | 626 | 616 | 467 | 385 | 2713 | |
| | | 0-64 yrs | SMR | 114.5 | 78.6 | 88.9 | 98.5 | 121.5 | 99.3 | p < 0.05 NL | 118.1 | 116.5 | 80.9 | 79.2 | 106.5 | 100.0 | n.s. |
| | | | OBS | 31 | 23 | 27 | 27 | 29 | 137 | | 19 | 19 | 14 | 12 | 14 | 78 | |
| | | 65+ yrs | SMR | 95.8 | 104.6 | 89.9 | 101.1 | 105.4 | 98.9 | p < 0.05 NL | 105.0 | 123.8 | 102.7 | 96.2 | 109.3 | 101.1 | p < 0.05 NL |
| | | | OBS | 690 | 835 | 706 | 645 | 559 | 3435 | | 600 | 607 | 602 | 455 | 371 | 2635 | |

*continues*

utable to pneumoconiosis, probably occupation-related, involving asbestos- and silica-processing workers [47]. This type of exposure mainly affects the most deprived groups of population [48], and indeed, this situation was observed in the Umbrian province of Terni, where a large steel-mill is located.

Finally, diseases of the digestive system are positively associated with SHE deprivation [49-51]. Indeed, cirrhosis, ulcers, diverticulitis and inflammatory bowel disease are usually associated with low SE status; this is due more to delays in diagnosis and therapy than to greater exposure to risk factors [51]. USHI trends on-

Tab. IV. *follows.*

| CAUSE | INDICES | AGE GROUPS | INDICATOR | MEN | | | | | | | WOMEN | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | Umbria | Trend | 1 | 2 | 3 | 4 | 5 | Umbria | Trend |
| DIGESTIVE DISEASES | NDI-U | All ages | SMR | 98.0 | 97.5 | 90.3 | 109.4 | 102.3 | 99.3 | n.s. | 85.8 | 100.0 | 103.8 | 111.0 | 95.4 | 99.2 | $p < 0.05$ NL |
| | | | OBS | 251 | 292 | 253 | 274 | 275 | 1345 | | 226 | 299 | 297 | 285 | 258 | 1365 | |
| | | 0-64 yrs | SMR | 88.7 | 97.7 | 76.6 | 93.4 | 143.3 | 99.1 | n.s. | 110.9 | 127.0 | 36.7 | 94.2 | 124.1 | 97.2 | n.s. |
| | | | OBS | 40 | 49 | 39 | 44 | 63 | 235 | | 16 | 20 | 6 | 14 | 17 | 73 | |
| | | 65+ yrs | SMR | 99.9 | 97.5 | 93.4 | 113.1 | 94.3 | 99.3 | $p < 0.05$ NL | 84.4 | 98.5 | 107.9 | 112.0 | 93.9 | 99.3 | $p < 0.05$ NL |
| | | | OBS | 211 | 243 | 214 | 230 | 212 | 1110 | | 210 | 279 | 291 | 271 | 241 | 1292 | |
| | USHI | All ages | SMR | 125.8 | 118.0 | 89.5 | 87.7 | 82.0 | 99.3 | $p < 0.05$ L↑ | 115.1 | 106.2 | 85.4 | 100.8 | 84.3 | 99.2 | $p < 0.05$ L↑ |
| | | | OBS | 292 | 360 | 273 | 223 | 197 | 1345 | | 341 | 334 | 263 | 255 | 172 | 1365 | |
| | | 0-64 yrs | SMR | 120.8 | 144.7 | 86.0 | 53.1 | 88.0 | 99.1 | $p < 0.05$ L↑ | 111.0 | 95.4 | 102.1 | 115.6 | 55.2 | 99.2 | n.s. |
| | | | OBS | 56 | 73 | 45 | 25 | 36 | 235 | | 17 | 15 | 17 | 17 | 7 | 73 | |
| | | 65+ yrs | SMR | 102.7 | 112.7 | 90.2 | 95.5 | 92.9 | 99.3 | $p < 0.05$ NL | 115.4 | 106.7 | 84.5 | 99.8 | 86.3 | 99.3 | $p < 0.05$ L↑ |
| | | | OBS | 236 | 287 | 228 | 198 | 161 | 1110 | | 324 | 319 | 246 | 238 | 165 | 1292 | |

ly partially confirmed the literature, with NL trends in males and females in all age-groups.
The above considerations seem to support the validation of USHI as an indicator of socio-economic and health-related inequalities.
A limit of USHI is that it cannot be considered a mere deprivation index. Indeed, as it is intended specifically to assess SE and health inequalities, overall mortality is one of its constituent variables. Therefore, it cannot be used to describe SE differences in a population, but only the SE differences tied to the health condition. Thus, although it is very useful for public health purposes, it cannot substitute a deprivation index for general purposes.
A second limit appears to be the local characterisation of the indices computed by means of this method, as the SHE descriptors may differ from area to area. In reality, however, given that the local indices are constructed according to the same method, they express the same conceptual definition of SHE deprivation even though they consider different SHE descriptors.
Instead, sharing the same method in order to identify SHE deprivation groups, even if they consider different SHE descriptors, they express the same conceptual definition of SHE deprivation. Therefore, similar segments of population in the different regions could be pooled, because they identify the same SHE differences and needs in people pertaining to different areas. At the European level, an analogous approach was adopted in the construction of the European Deprivation Index [52].

## Conclusions

By connecting SE findings with some explanations of health conditions described in the literature, the present study confirms that the construction of regional indices of SHE inequalities allows us to formulate specific hypotheses regarding the reasons behind health outcomes in a population and, consequently, to make suggestions concerning the corrective actions to undertake.
Our aim was to provide a valid and reliable method of computing SE and health inequality-related indices at the regional level, in order to better analyse the specific elements associated with the health condition of the population.
The present findings demonstrated that the USHI better represented the association between health and inequalities, and may provide a useful guide to the allocation of regional health resources.
In conclusion, regional indices computed in the same way as the USHI could be adopted elsewhere, in order to draw up specific strategies to reduce inequalities in health, thereby contributing to the sustainability of the health system and to the evaluation of the outcomes of the policies implemented.


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## Conflict of interest statement

The authors declare no conflict of interest.

## Authors' contributions

RL: main author; research protocol, development of the analyses and author for paragraphs "Material and Methods" and "Results".
GM: author for paragraphs "Introduction" and "Discussion", linguistic revision.
FB: data provider and data quality check, contribution to methods and analysis.
AG: quality check for data analysis and results.
FS: contribution to paragraphs "Discussion" and "Conclusion", text revision, availability of Umbria Region Cancer and Mortality Registries.
FLR: contribution to pargaragraphs "Introduction" and "Conclusion", availability of Umbria Region Cancer and Mortality Registries.
MV: author of paragraph "Conclusion", contribution to all paragraphs, coordination of the study.

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Tab. SI. Municipalities and sub-municipalities, by SE deprivation group and USHI value.

| Very high deprivation | High deprivation | Medium deprivation | Low deprivation | Very low deprivation | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Municipality/ Sub-municipality | USHI value | Municipality/ Sub-municipality | USHI value | Municipality/ Sub-municipality | USHI value | Municipality/ Sub-municipality | USHI value | Municipality/Sub-municipality | USHI value |
| Poggiodomo | 0.02 | Foligno 2 | 61.87 | Foligno 1 | 68.01 | Perugia 4 | 78.25 | Avigliano Umbro | 83.02 |
| Polino | 39.04 | Narni | 61.94 | Perugia 5 | 68.10 | Campello sul Clitunno | 78.42 | Cannara | 83.27 |
| Foligno 3 | 42.75 | Arrone | 62.75 | Todi | 68.46 | Perugia 2 | 78.73 | Montefalco | 83.28 |
| Terni 5 | 45.42 | Nocera Umbra | 62.82 | Tuoro sul Trasimeno | 69.22 | Porano | 78.86 | Spello | 83.66 |
| Preci | 49.21 | Montefranco | 63.42 | Paciano | 69.31 | Gualdo Cattaneo | 79.28 | Fratta Todina | 85.33 |
| Terni 4 | 51.32 | Otricoli | 63.71 | Cascia | 69.50 | Montecastrilli | 79.64 | Magione | 85.87 |
| Parrano | 53.36 | Guardea | 63.74 | Alviano | 69.95 | Fossato di Vico | 80.09 | Bevagna | 85.89 |
| Terni 3 | 54.95 | Ficulle | 64.10 | Perugia 6 | 70.71 | Piegaro | 80.19 | Perugia 1 | 86.53 |
| Calvi dell'Umbria | 55.53 | Montecchio | 64.35 | Attigliano | 71.15 | Marsciano | 80.32 | Sigillo | 86.58 |
| Penna in Teverina | 56.36 | Orvieto | 65.33 | Gubbio | 71.30 | San Venanzo | 80.34 | Montone | 87.43 |
| Monteleone d'Orvieto | 56.37 | Amelia | 65.83 | Allerona | 71.40 | Città di Castello | 80.61 | Trevi | 88.60 |
| Vallo di Nera | 56.59 | Ferentillo | 65.85 | Sant'Anatolia di Narco | 71.66 | Collazzone | 81.23 | San Giustino | 90.92 |
| Sellano | 56.70 | Gualdo Tadino | 66.03 | Pietralunga | 72.20 | Valtopina | 81.81 | Monte Santa Maria Tiberina | 92.12 |
| Terni 2 | 57.65 | Città della Pieve | 66.14 | Lisciano Niccone | 72.65 | Panicale | 82.01 | Deruta | 92.94 |
| Perugia 7 | 59.37 | Giove | 66.19 | Lugnano in Teverina | 73.23 | Giano dell'Umbria | 82.05 | Torgiano | 94.51 |
| Terni 1 | 59.59 | Castiglione del Lago | 66.64 | Castel Viscardo | 73.38 | Valfabbrica | 82.16 | Bettona | 95.16 |
| Stroncone | 60.46 | Scheggino | 66.98 | Fabro | 73.88 | Castel Ritaldi | 82.63 | Bastia | 95.89 |
| Monteleone di Spoleto | 60.53 | Norcia | 67.15 | Passignano sul Trasimeno | 74.46 | Assisi | 82.69 | Corciano | 95.89 |
| Montegabbione | 60.58 | Spoleto | 67.21 | Costacciaro | 74.62 | | | Citerna | 99.98 |
| Castel Giorgio | 61.61 | Cerreto di Spoleto | 67.24 | San Gemini | 74.64 | | | | |
| | | Baschi | 67.59 | Massa Martana | 74.70 | | | | |
| | | Acquasparta | 67.88 | Perugia 3 | 74.76 | | | | |
| | | | | Umbertide | 75.30 | | | | |
| | | | | Scheggia e Pascelupo | 76.44 | | | | |
| | | | | Monte Castello di Vibio | 77.40 | | | | |