The Health Potential of Neighborhoods: A Population-Wide Study in The Netherlands

Louise H. Dekker (l.h.dekker@umcg.nl)  
University Medical Centre Groningen: Universitair Medisch Centrum Groningen  
Richard H Rijnks  
Rijksuniversiteit Groningen  
Jochen O. Mierau  
Rijksuniversiteit Groningen

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Abstract

**Background:** While differences in population health across neighborhoods with different socioeconomic characteristics are well documented, health disparities across neighborhoods with *similar* socioeconomic characteristics are less well understood. Studying the determinants of variation of health among neighborhoods with similar socio-economic characteristics is pivotal for gaining insight into where health potential lies. We aimed to estimate population health inequalities, both within and between neighborhoods with similar socio-economic status, and assessed the association of neighborhood characteristics and socio-economic spillover effects from adjacent neighborhoods.

**Methods:** Based on whole-population data from the Netherlands we determined the percentage of inhabitants with good/very good self-assessed health (SAH) as well as the percentage of inhabitants with at least one chronic disease (CD) in 11,504 neighborhoods. Neighborhoods were classified by quintiles of a composite NSES score. Spatial models were estimated by including the spatially weighted NSES of adjacent neighborhoods.

**Results:** Substantial population health disparities in SAH and CD both within and between neighborhoods NSES quintiles were observed, with the largest SAH variance in the lowest NSES group. These differences were partially explained by neighborhood density and the percentage of inhabitants ≥ 65 years old. Neighborhoods adjacent to higher SES neighborhoods showed a higher SAH and a lower prevalence of CD, adjusted for other explanatory variables. Policy simulations indicate how modest changes in NSES among groups of neighborhoods with similar socio-economic characteristics can contribute to population health, partially due to spatial spillovers.

**Conclusion:** Population health differs substantially among neighborhoods with similar socioeconomic characteristics, which can partially be explained by a spatial socio-economic spillover effect. This provides interesting leads to policy design aimed at improving population health outcomes of deprived neighborhoods focusing on health potential.

**Background**

A large body of literature documents a socioeconomic gradient in population health at the neighborhood level. More affluent neighborhoods exhibit better health outcomes such as a lower risk of stroke, diabetes, asthma, and higher values of a variety of quality of life measures. Furthermore, low neighborhood socioeconomic status (NSES) is associated with relatively high healthcare costs, due to, amongst others, more hospital admissions. As there is a growing interest in evidence-based health policy, it is important to further our understanding of potential mechanisms that may both improve population health and reduce neighborhood health inequalities.

While differences in population health across neighborhoods with different socioeconomic characteristics are well documented, health disparities - and their causes - across neighborhoods with
similar socioeconomic characteristics are less well understood. Ferrer and Palmer speculate that there may be an interaction between NSES and individual characteristics, where the effect of NSES on health is exacerbated when individual characteristics are unfavorable\textsuperscript{9}. Recently, lifestyle has been found to act as such a potential individual determinant that causes variation in health within neighborhoods with similar socioeconomic characteristics\textsuperscript{10}. Additionally, contextual neighborhood determinants may also play a role. For example, population density has been found to largely account for cardiovascular health disparities between metropolitan and smaller community areas\textsuperscript{11}.

Health outcomes in a given neighborhood may also be affected by the health status of the surrounding neighborhoods, i.e. spatial spillover effects. These spillovers may occur when there is social interaction and movements among individuals located in a close spatial proximity which extends beyond the arbitrary defined neighborhood boundaries\textsuperscript{1,12}. The vast majority of existing studies\textsuperscript{13-16} do not account for the potential of spatial relationships between geographic locations in their multilevel regression analyses\textsuperscript{17}. Therefore, Diez Roux\textsuperscript{13}, Spielman and Yoo\textsuperscript{18} and Perchoux et al.\textsuperscript{19} have criticized that the neighborhood characteristics surrounding the residents are not adequately represented and analyzed in the current literature. This is unfortunate as there is a strong basis to suggest that “where we live” matters for our health over and above “who we are”\textsuperscript{20}. We aimed to estimate population health inequalities, both within and between neighborhoods with similar socio-economic status, and assessed the association of neighborhood characteristics and socio-economic spillover effects from adjacent neighborhoods.

**Methods**

**Data**

We used population health and lifestyle measures from the Dutch Public Health Monitor of the National Institute for Public Health (RIVM). The Dutch Public Health Monitor is held every four years and is based on a national survey of over 400,000 inhabitants, containing data on self-reported health, health perception, and health-related behaviours of persons aged 19 years and older. Using structured additive regressions, the survey data is translated into valid small area estimates that can potentially be used for health policy decisions\textsuperscript{21}. Neighborhood socioeconomic status (NSES) was derived from Statistics Netherlands\textsuperscript{24}. The NSES was calculated using Nonlinear Iterative PArtial Least Squares Principal Component Analysis (NIPALS), based on neighbourhood income statistics (percentage people in lower 2 quintiles of national income, percentage people in highest quintile), social welfare reliance (percentage of people on benefits, disability benefits, or unemployment benefits), and housing market characteristics (average estimated housing-price, percentage owner-occupied, percentage council housing). The algorithm accommodates missing values in PCA analysis, allowing for more neighbourhoods to be included in the paper. The scores on the first component (factor) defined the NSES score and were subsequently categorized into quintiles. The Statistics Netherlands Neighbourhood dataset contains 12,822 neighbourhoods. Of these, 1,318 have no socio-economic data due to low numbers of inhabitants, representing a total of 21,520 inhabitants (0.1% of the total dataset). These neighbourhoods were
removed from the data. All other neighbourhoods were included in the analysis. The NSES data combined
with the neighborhood health data is available for 11,504 neighbourhoods with an average population of
1,473 individuals per neighborhood.

Dependent variables

From the Dutch Public Health Monitor data we used two health indicators. First, we obtained the
percentage of individuals who indicated to be in good or excellent health, i.e. SAH. Second, the
percentage of individuals suffering from one or more long standing (> 6 months) illnesses or health
problems, i.e. CD, was used. To corroborate our results, the following four lifestyle indicators were taken
into account in this study, all being measured at the neighborhood level: 1) the percentage of non-
smokers; 2) the percentage of those that adhere to the 2016 Dutch alcohol recommendation; 3) the
percentage of individuals who complied with the 2016 Healthy Exercise Guideline; 4) the percentage of
individuals with overweight (body mass index $\geq$ 25 kg/m²).

Explanatory contextual variables

Three potential explanatory contextual factors were assessed. The first two variables were 1) the
percentage of inhabitants over the age of 65 years, and 2) the population density of the neighborhood,
both provided by Statistics Netherlands at the neighborhood level. As a third explanatory variable we
calculated a spatially lagged term for NSES to assess spillover effects of adjacent (neighborhood) SES.
For the spatial lag we construct a spatial weights matrix consisting of all neighbourhoods within a 12.5
kilometer radius (centroid to centroid), resulting in a minimum of one neighbour per neighbourhood.
Weights were calculated using $1/distance^2$, and subsequently row-standardized to account for
heterogeneity in the number of neighbors.

Statistical analysis

Health and contextual characteristics of quintiles of NSES scores were analyzed by descriptive statistics
(mean and SD). Kernel density plots were derived to visualize the distribution of SAH and CD across
quintiles of NSES scores. The amount of within and between quintiles NSES variance in SAH health and
CD was calculated using ANOVA. Linear regression models were applied to assess the role of the
explanatory contextual variables in the variation of SAH and CD across quintiles of NSES scores.
Subsequent to the parsimonious model, population density and the percentage of inhabitants aged over
65 were added (Model 2). In Model 3, we additionally included the spatially lagged term for NSES to allow
for spillover effects of adjacent NSES.

Furthermore, we estimate what effect two hypothetical policy scenarios might have on SAH or CD. The
first scenario specifies that the lowest 10% of NSES scores (lowest half of the first quintile) are targeted
to improve to the median NSES in the lowest quintile. This scenario specifically targets the within NSES
group potential. The second scenario involves improving the NSES for the lowest quintile to the NSES of
the equivalent neighborhood in the second quintile, i.e. moving up on the NSES ladder. To do so,
generalized additive models (GAM) were used to obtain non-linear estimates for NSES. By using GAMs we obtained a reasonably continuous estimate of the non-linearity in the association between NSES and health, as opposed to the coarser group-wise (i.e. hierarchical models) or more constrained estimates a linear polynomial model would provide. This detail enhances the accuracy of the estimates for our scenarios. For both scenarios, we assess both the direct impacts on SAH or CD, that is the impact on the neighborhood itself, and the indirect impact, the impact a change has through the spatial spillover effect. To assess the direct impact on SAH or CD, we compute the effect on these health indicators using the parameters estimated in our GAM with the hypothetical NSES values, using the spatially lagged NSES from the original data. Second, we recalculate the spatially lagged NSES variable to include the improved regional NSES scores and predict the SAH or CD using the GAMs. This second prediction includes both the direct and the indirect effect. To isolate the indirect effect, we take the difference between the second and first predictions. As the baseline for comparison we use the predicted outcomes from our baseline GAMs with the observed independent variables. The measured values for NSES and SAH in the original dataset are composed of the model prediction + residual. By using only the prediction we avoid comparing our scenarios with the baseline residual. All analyses were performed in R, for the NIPALS we used the NIPALS R package, spatial data manipulations were performed using the spdep package.

Results

Descriptive statistics

The descriptive statistics reveal a typical stepped relation between NSES and health (Table 1). As a neighborhood moves along the socioeconomic ladder the share of individuals indicating being in good or excellent health increases, while the prevalence of CD decreases. Additionally, as a corroboration, the data shows that higher NSES scores is characterized with better lifestyles, i.e. less overweight, less smoking and participating considerably more in sports activities. Those in the highest NSES quintile are however, less likely to comply with the Dutch alcohol norm. Albeit less pronounced, higher NSES scores were characterized by lower population density and a smaller share of individuals older than 65 years of age. Kernel density plots revealed that there is overlap between the percentage of SAH and CD across the quintiles of NSES scores (Supplementary Figure S1a and S1b).

We find substantial population health disparities in SAH and CD both between neighborhoods with different and neighborhoods with similar socioeconomic characteristics (Supplementary Table S1). When we decompose the variation of SAH, CD and lifestyle measures into within and between quintiles of NSES, the within variation is similar to the between variation.

Linear regression analysis shows that the average SAH in the first quintile is just under ten percentage points lower than in the third quintile (Table 2). Population density is negatively associated with SAH, as is the proportion of individuals aged 65 or older. The coefficient for the spatially weighted NSES variable is significant and positive: neighborhoods adjacent to higher NSES neighborhoods have on average higher SAH, while neighborhoods adjacent to lower NSES neighborhoods are negatively affected (model
3). In this model, the direct association between NSES and SAH remained intact (p < 0.001). Albeit in the opposite direction, the same results were obtained for CD (Table 3).

**Policy scenarios**

Table 4 shows the change in the percentage of individuals with SAH or CH based on two hypothesized policy scenarios targeted at increasing the health potential of the lowest NSES group by decreasing the SES within and between quintiles of NSES scores. First, if the NSES in the lowest half of the lowest NSES quintile would be increased to its quintile median, the direct effect on SAH would be an increase of 5.6% reporting to be in good or excellent health in the lowest NSES group. Spillovers into regions of higher NSES also occur, but are smaller. Spatial spillovers would lead to an additional increase of 1.7% in all NSES groups. The second scenario revealed that when the lowest quintile of NSES scores would move up on the NSES ladder, i.e. from Q1 to Q2, there would be an increase in those reporting to have good or excellent health (i.e. 18.7%), and an additional 4.4% would be achieved due to spatial spillovers. Albeit smaller, also a substantial decrease in CD may be achieved by these hypothetical policy scenarios.

**Discussion**

In this paper we aimed to identify to what extent health disparities in subjective and objective population health measures occur across and within groups of similar NSES scores, and to assess the role of a set of potential explanatory contextual variables. In addition, we aimed to show the effect that two hypothesized policy interventions aimed at increasing the NSES of the lowest NSES group may have on population health. We found substantial population health disparities in the percentage of individuals reporting to be in good or excellent health (i.e. SAH) and the percentage of individuals with one or more CD, both between neighborhoods with different and neighborhoods with similar socioeconomic characteristics. These differences were only partially explained by population density and the share of individuals over 65 years of age. Neighborhoods adjacent to higher SES neighborhoods showed a higher SAH and a lower prevalence of CD, adjusted for other explanatory variables. Two hypothetical policy scenarios targeting the lowest NSES group revealed substantial health gains resulting from both direct effects (for the lowest NSES group) and indirect effects (for all NSES groups) due to spatial spillovers effects.

The substantial variation in subjective and objective population health measures (as well as lifestyle factors) between neighborhoods with similar socioeconomic characteristics presented in this paper, may potentially directly provide policy anchors for interventions that improve population health in disadvantaged neighborhoods without changing socioeconomic characteristics, which are notoriously more difficult to alter. Only a handful of studies have documented the differences in health outcomes between socioeconomically similar neighborhoods. Focusing on cost data from the Netherlands, de Boer et al. showed that healthcare costs of the most deprived NSES exhibited substantial variation, with some displaying health care costs well below the average costs of high NSES neighborhoods. In addition, Ferrer and Palmer observed considerable variability in self-rated health within socioeconomic strata.
There was a resilient subgroup of lower SES people whose self-rated health remained excellent throughout life, while in a vulnerable group of low SES persons a rapid deterioration in health status as they reach middle age was observed. Clearly, more insight is needed using a priori designed studies to evaluate the potential of social determinant-related interventions to improve health outcomes and reduce health disparities within and across groups of neighborhoods with similar socioeconomic status.

In this study we showed the potential role of population density and the effect of spatial spillovers in the variation in subjective and objective health within and across neighborhoods with similar socioeconomic characteristics. Neighborhoods adjacent to higher NSES neighborhoods showed on average higher SAH and lower prevalence of CD. This seems especially true for neighborhoods with the lowest NSES scores, as the present results showed that this group was most affected by regional SES spillovers effects. The underlying motivation for spatial thinking is grounded in Tobler's first law of geography “everything is related to everything else, but near things are more related than distant things”\(^26\). These, in turn, convey a spatial perspective that the characteristics of a neighborhood are not merely shaped by a particular bounded location, but are also shaped by the characteristics of its surrounding locations. While the mechanisms behind the observed effect of socioeconomic spillovers on health needs further study, it may already provide interesting leads to policy design aimed at improving population health outcomes of deprived neighborhoods. For example, the present results may urge for designing more socio-economically mixed regions of neighborhoods, with the idea that poor neighborhoods could benefit from the presence of, and interaction with more affluent neighborhoods\(^27\).

Additionally, this study presented an evidence base for the potential of improving population health when targeting fundamental causes of health disparities in the most deprived neighborhoods. Small changes in NSES might already have substantial improvements in SAH and CD. To further illustrate the potential of such interventions, de Boer et al. calculated potential health care cost savings by reducing health differences between neighborhoods with comparable income and education levels\(^7\). If each neighborhood had the same health care expenditures as the average neighborhood with the same socioeconomic characteristics, health care costs could still be reduced by 2.4% of overall health care expenditures. As shown in the present study, not only the target group may experience substantial health gains through such intervention, also the total population might benefit from it, due to the potential of spatial spillover effects. Previously this was also concluded by Benjamin-Chungough et. al, who stated that interventions may benefit not only direct recipients but also those who did not receive the intervention but are connected to the recipients\(^28\).

A further and crucial implication of the within group health disparities is that inequities in health apply to everyone. Therefore, social action should deal with the entire gradient, and all of society, not only with those at the bottom. Therefore, questions about the effect of universal versus targeted prevention strategies on population health and health inequalities, and the role that fundamental causes play in population health, are critical to the articulation of effective public health planning strategies. Ideally, a universal course in increasing SES potential must be chosen, according to the theory of the proportionate
universalism of the British epidemiologist Michael Marmot\textsuperscript{29,30}. That means that prevention policy, while targeting all citizens, is being complemented by support for certain target groups. The intensity of this targeted support is determined by the degree of vulnerability of the target group. Additionally, positioning health equity as a key performance indicator in all social and economic policy has the potential to drive significant reductions in health inequities.

While we used rich, whole-population data, on both subjective and objectively measured health outcomes, this study is not without limitations. First of all, because our study focused on the neighborhood level, the findings may not be fully transferable to policies and interventions aimed at the individual level. Second, because of the unique characteristics of the Dutch health care system and Dutch society (e.g., the country's rather egalitarian socioeconomic structure), the outcomes of this research may not be fully generalizable to other countries. However, because of the scope of this research, we believe that the findings provide valuable insights, as would similar investigations in other countries. Third, because we used a cross-sectional approach, the associations presented are not necessarily indicative of causal relations.

Conclusion

Population health differs substantially among neighborhoods with similar socioeconomic characteristics, which can partially be explained by a spatial socioeconomic spillover effect. The mechanisms behind these socioeconomic spillovers need further study, but may already provide interesting leads to policy design aimed at improving population health outcomes of deprived neighborhoods.

List Of Abbreviations

- BMI body mass index
- CD chronic diseases
- GAM generalized additive models
- NSES neighborhood socioeconomic status
- SES socioeconomic status
- SAH self-assessed health

Declarations

Ethics approval and consent to participate

Not applicable
Consent for publication

Not applicable

Availability of data and materials

The data may be requested from The National Institute for Public Health and Statistics Netherlands directly

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

All authors contributed to the design and content of the study. RR carried out the data analyses, and provided all figures and tables. LD drafted the manuscript with contributions from all the authors. All authors reviewed and edited the manuscript. All authors approved the final manuscript.

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Tables

Table 1. Descriptive statistics on neighborhoods characteristics by quintiles of neighborhood socioeconomic status
|                                | Total  | NSES Q1 | NSES Q2 | NSES Q3 | NSES Q4 | NSES Q5 |
|--------------------------------|--------|---------|---------|---------|---------|---------|
| Neighbourhoods (n)            | 11,504 | 2,300   | 2,301   | 2,301   | 2,301   | 2,301   |
| Self-assessed health (% , SD) | 76.9   | 68.7    | 75.4 (4.4) | 78.6 (3.9) | 80.1 (3.7) | 81.7 (4.5) |
| Chronic diseases (% , SD)     | 33.1 (5.4) | 38.7 (5.4) | 34.7 (3.8) | 31.9 (3.8) | 30.59 (4.0) | 29.7 (4.5) |
| Overweight (% , SD)           | 49.9 (5.7) | 52.2 (6.8) | 51.8 (5.1) | 50.2 (4.7) | 48.7 (4.5) | 46.9 (5.3) |
| Non-smokers (% , SD)          | 20.2 (5.1) | 26.41 (4.8) | 21.0 (3.6) | 18.8 (3.4) | 17.9 (3.3) | 16.9 (3.6) |
| Sports (% , SD)               | 49.4 (8.1) | 43.1 (7.7) | 47.4 (6.2) | 50.3 (6.3) | 52.1 (6.7) | 54.0 (8.2) |
| Alcohol recommendation (% , SD)| 39.2 (7.4) | 45.9 (8.5) | 39.9 (6.0) | 37.4 (5.6) | 37.0 (5.6) | 36.0 (6.2) |
| Neighborhood density (n)      | 3,169 (4,004) | 5,916 (4,722) | 3,646 (3,730) | 2,521 (3,465) | 2,038 (3,296) | 1,727 (3,096) |
| Over 65 years (% , SD)        | 19.1 (9.2) | 19.5 (10.9) | 20.2 (8.3) | 18.6 (7.4) | 17.9 (8.0) | 19.1 (10.7) |

Table 2. SAH Model estimates
### Table 3. Chronic Diseases model estimates

|                  | Model 1: β | Model 1: t-value | Model 2: β | Model 2: t-value | Model 3: β | Model 3: t-value |
|------------------|------------|------------------|------------|------------------|------------|------------------|
| (Intercept)      | 78.62***   | 788.50           | 84.41***   | 692.09           | 84.33***   | 700.20           |
| NSES Q1          | -9.91***   | -70.26           | -8.96***   | -71.80           | -8.27***   | -64.02           |
| NSES Q2          | -3.18***   | -22.60           | -2.51***   | -20.87           | -2.39***   | -20.12           |
| NSES Q4          | 1.48***    | 10.52            | 1.17***    | 9.84             | 1.13***    | 9.59             |
| NSES Q5          | 3.02***    | 21.46            | 2.98***    | 24.91            | 2.83***    | 23.90            |
| Neighborhood density | 0.00***    | -19.61           | 0.00***    | -17.89           |            |                  |
| Over 65 years    | -0.28***   | -67.05           | -0.28***   | -68.46           |            |                  |
| Spatial SES spillover |          |                  |            |                  | 176.11***  | 17.54            |

*** p < 0.001, ** < 0.01, * < 0.05, ref NSES is Q3

### Table 4. Policy scenarios: Expected changes in self assessed health and chronic diseases

|                  | Model 1: β | Model 1: t-value | Model 2: β | Model 2: t-value | Model 3: β | Model 3: t-value |
|------------------|------------|------------------|------------|------------------|------------|------------------|
| (Intercept)      | 31.86***   | 352.360          | 25.5097*** | 259.393          | 25.58***   | 256.490          |
| NSES Q1          | 6.82***    | 53.34            | 5.98***    | 59.46            | 5.29***    | 51.15            |
| NSES Q2          | 2.79***    | 21.88            | 2.11***    | 21.77            | 1.99***    | 20.95            |
| NSES Q4          | -1.33***   | -10.46           | -1.02***   | -10.63           | -0.98***   | -10.37           |
| NSES Q5          | -2.15***   | -16.85           | -2.15***   | -22.36           | -2.00***   | -21.16           |
| Neighborhood density | 0.00***    | 19.44            | 0.00***    | 17.38            |            |                  |
| Over 65 years    | 0.31***    | 93.71            | 0.32***    | 96.34            |            |                  |
| Spatial SES spillover |          |                  |            |                  | -178.14*** | -22.17           |

*** p < 0.001, ** < 0.01, * < 0.05, ref NSES is Q3
### Scenario 1: Improvement of lowest 10% NSES Neighbourhoods

|        | Self assessed health - Direct effect | Self assessed health - Indirect effect | Chronic diseases - Direct effect | Chronic diseases - Indirect effect |
|--------|--------------------------------------|----------------------------------------|---------------------------------|-----------------------------------|
| NSES Q1 | 5.66                                 | 0.53                                   | -2.25                           | -0.52                             |
| NSES Q2 | -                                    | 0.32                                   | -                               | -0.33                             |
| NSES Q3 | -                                    | 0.26                                   | -                               | -0.33                             |
| NSES Q4 | -                                    | 0.28                                   | -                               | -0.35                             |
| NSES Q5 | -                                    | 0.33                                   | -                               | -0.37                             |

### Scenario 2: Improvement of lowest Quintile NSES to second lowest Quintile NSES

|        | Self assessed health - Direct effect | Self assessed health - Indirect effect | Chronic diseases - Direct effect | Chronic diseases - Indirect effect |
|--------|--------------------------------------|----------------------------------------|---------------------------------|-----------------------------------|
| NSES Q1 | 18.72                                | 1.64                                   | -8.6                            | -1.89                             |
| NSES Q2 | -                                    | 0.82                                   | -                               | -1.19                             |
| NSES Q3 | -                                    | 0.61                                   | -                               | -1.04                             |
| NSES Q4 | -                                    | 0.67                                   | -                               | -1.15                             |
| NSES Q5 | -                                    | 0.70                                   | -                               | -1.03                             |