Individual/Neighborhood Social Factors and Blood Pressure in the RECORD Cohort Study

Which Risk Factors Explain the Associations?

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Abstract—Recent studies have started to suggest that, beyond effects of individual socioeconomic profiles, socioeconomic characteristics of residential neighborhoods are independently associated with blood pressure. However, mechanisms involved in these associations remain unknown. To distinguish between different mechanisms, we investigated whether specific risk factors of hypertension (physical inactivity, alcohol consumption, smoking, body mass index, waist circumference, and resting heart rate) intervene as mediators in the associations between individual or neighborhood socioeconomic characteristics and systolic blood pressure. We relied on data from the RECORD Cohort Study (Residential Environment and COronary heart Disease) on 5941 participants recruited in 2007–2008, aged 30 to 79 years, residing in 1824 neighborhoods in the Paris metropolitan area. Systolic blood pressure increased independently and regularly with both decreasing individual education and decreasing residential neighborhood education. Body mass index/waist circumference and resting heart rate mediated an appreciable share of the associations between education and blood pressure and, adding validity to the finding, were the 2 most significant mediators for the effects of both individual education and neighborhood education. We found that 52% (95% CI: 25% to 79%) of the association between neighborhood education and blood pressure was mediated by body mass index/waist circumference and 20% (95% CI: 5% to 36%) by resting heart rate. Future research will have to clarify the exact mechanisms through which body weight and shape and resting heart rate intervene as mediators in the associations between individual/neighborhood education and blood pressure. **(*Hypertension*. 2010;55:769-775.)**

Key Words: blood pressure ■ socioeconomic factors ■ residence characteristics ■ social environment ■ heart rate ■ obesity

Considering socioeconomic characteristics is useful both in the clinical setting to improve risk stratification of patients at risk of hypertension and, from a public health perspective, to identify population-level determinants of blood pressure when defining interventions.[1] Regardless of the aim, recent studies suggest that a better assessment of socioeconomic differences in blood pressure may be obtained by considering social circumstances both at the individual level and at the residential neighborhood level.[2–5] To date, fewer studies have quantified neighborhood socioeconomic influences on blood pressure than on behavioral risk factors of cardiovascular diseases (smoking and physical inactivity) or obesity.[6]

As recently emphasized,[7] knowledge useful for public health action is identifying the different mechanisms underlying associations between individual/neighborhood socioeconomic characteristics and blood pressure (eg, through known risk factors of hypertension) on which it would be possible to intervene to address social disparities in blood pressure.[1,8] However, on the one hand, the very few studies that investigated intermediate mechanisms through which individual socioeconomic variables relate to blood pressure[9] have generally included all of the mediating risk factors simultaneously in the models, not permitting us to disentangle the independent mediating role of different risk factors of hypertension.[1] On the other hand, the only study that investigated mediating processes between neighborhood socioeconomic characteristics and blood pressure has only considered weight status as a mediator,[2] not allowing us to compare different risk factors according to their importance in explaining social environment effects on blood pressure. Therefore, our aims were to assess whether individual and neighborhood socioeconomic characteristics influence blood pressure and to investigate the extent to which health behavior, body weight and shape, and resting heart rate may contribute to these relationships.

Methods

Population

The RECORD Cohort Study (Residential Environment and COronary heart Disease) includes 7293 participants who were recruited between

Received September 28, 2009; first decision October 20, 2009; revision accepted December 23, 2009.

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Hypertension is available at http://hyper.ahajournals.org

DOI: 10.1161/HYPERTENSIONAHA.109.143206

March 2007 and February 2008. The participants benefitted from a free medical checkup, offered every 5 years by the French National Health Insurance System for Salaried Workers to all working and retired employees and their families. Participants were recruited without a priori sampling during these 2-hour–long preventive checkups conducted by the Centre d'Investigations Préventives et Cliniques[10,11] in 4 of its health centers, located in the Paris metropolitan area (Paris, Argenteuil, Trappes, and Mantes-la-Jolie). Eligibility criteria were age 30 to 79 years, ability to fill out the study questionnaires, and residence in 1 of 10 (of 20) administrative divisions of Paris or 111 other municipalities of the metropolitan area selected a priori. Among those who came to the health centers and who were eligible on the basis of age and residence, 10.9% were not selected for participation because of linguistic or cognitive difficulties in filling out questionnaires. Individuals selected for participation were informed about the study by trained survey technicians. Of these, 83.6% accepted to participate and completed the data collection protocol.

Participants were accurately geocoded on the basis of their residential address in 2007–2008. Research assistants corrected all of the incorrect or incomplete addresses with the participants by telephone. Extensive investigations with local departments of urban planning were conducted to complete the geocoding. Precise spatial coordinates and block group codes were identified for 100% of the participants. The study protocol was approved by the French Data Protection Authority.

In the present study, only participants recruited in the Paris health center were considered. After excluding individuals with missing values for selected variables (see below), 5941 participants, living in 110 different municipalities or 1824 neighborhoods, were included in the analyses.

Measures

Systolic Blood Pressure

During the health checkup, supine brachial blood pressure was measured by trained nurses 3 times in the right arm after a 10-minute rest period, using a manual mercury sphygmomanometer.[10] A standard cuff size was used, but a large cuff was utilized if necessary. The first Korotkoff phase was used to define systolic blood pressure (SBP; please see the online Data Supplement at http://hyper.ahajournals.org for comparable analyses conducted for diastolic blood pressure). The mean of the last 2 measurements was taken as the outcome.[11]

Individual Sociodemographic Variables

Various sociodemographic characteristics of participants were considered: age, sex, marital status, individual education, parental education, occupation, employment status, household income, self-reported financial strain, dwelling ownership, and Human Development Index of each participant's country of birth. Age was considered as a continuous variable. Marital status was coded in 2 classes: living alone or as a couple. Education was divided in 4 classes: (1) no education; (2) primary education and lower secondary education; (3) higher secondary education and lower tertiary education; and (4) upper tertiary education. For parental education level, we created an education variable by adding the mother's and father's education level (1: primary school or less; 2: secondary school; and 3: tertiary school) and divided the resulting score into 3 classes (2, 3 to 4, and 5 to 6). Mother's and father's education were also considered separately.[12] Regarding occupation, in accordance with the French National Institute of Statistics and Economic Studies, 4 categories were distinguished: (1) blue-collar workers; (2) low white-collar workers; (3) intermediate occupations; and (4) high white-collar workers. Employment status was coded in 3 categories: employed, unemployed, and retired. Household income adjusted for household size was divided into 4 categories. A binary variable for self-reported financial strain and a binary variable for dwelling ownership were determined. Each individual's self-reported country of birth was also taken into account. We followed an approach by Merlo[13] in attributing to each individual the 2004 Human Development Index of his/her country of birth, as a proxy of the country's social development level. Following the United Nations Development Programme,[14] a binary variable was used to distinguish people born in low-development countries (Human Development Index <0.5) from others.

Antihypertensive Medication Use

By merging Système d'Information Inter Régimes de l'Assurance Maladie or Federative Information System of Sick Insurance data for all of the reimbursed healthcare consumption in participants in 2006–2008 to the RECORD database, we created a binary variable indicating whether individuals had been reimbursed for any antihypertensive medication over the previous year.

Risk Factors of High Blood Pressure

The following risk factors of high blood pressure were considered as possible mediators in the associations between socioeconomic variables and blood pressure: physical inactivity, alcohol consumption, smoking, body mass index, waist circumference, and resting heart rate. Family history of hypertension was also taken into account for adjustment.

Family history of hypertension was assessed from the questionnaire. Participants were asked whether they were physically active (at work, during transportation, or during leisure time) for an equivalent of >1 hour of walking per day. Alcohol consumption was coded in 4 categories: never drinker, former drinker, light drinker, and drinker (>2 glasses per day for women and 3 glasses per day for men). For smoking, we distinguished between nonsmoker, former smoker, and current smoker.

Height (using a wall-mounted stadiometer) and weight (using calibrated scales) were recorded by a nurse.[10] Body mass index was divided into 3 categories (normal: <25 kg/m^2, overweight: 25 to <30 kg/m^2, and obese: ≥30 kg/m^2). Waist circumference was measured in centimeters using an inelastic tape placed midway between the lower ribs and iliac crests on the midaxillary line.[11] It was divided into 3 categories (<94 cm, 94 to ≤102 cm, and >102 cm among men; <80 cm, 80 to ≤88 cm, and >88 cm among women). Resting heart rate was measured by ECG after a 5- to 7-minute rest period[10] and was subsequently divided into 3 classes: <60 bpm, 60 to <70 bpm, and ≥70 bpm (70 rather than 80 bpm was used as a cutoff because only 4.8% of the participants had a resting heart rate ≥80 bpm).

Neighborhood Socioeconomic Variables

Neighborhoods were assessed as census block groups.[2] These 1824 local units were defined from the 1999 census so as to be relatively homogeneous in terms of sociodemographic and housing characteristics. The median number of residents per neighborhood was 2393 in 1999 (interquartile range: 2084 to 2903).

The following socioeconomic variables were defined at the neighborhood level: (1) the proportion of residents aged ≥15 years with an upper tertiary education (1999 census); (2) median income in 2005 (Tax Registry of Direction Générale des Impôts, General Directorate of Taxation); and (3) mean value of dwellings sold in 2003–2007 (Paris-Notaries). All of the neighborhood sociodemographic variables were divided into 4 categories composed of a similar number of individuals.

Statistical Analysis

We excluded 176 participants with missing information for SBP and 50 individuals with missing data for individual education. Individuals with missing information for any of the mediating risk factors were also excluded, resulting in a final sample of 5941 individuals.

Initial Multilevel Analyses

To account for the strong within-neighborhood correlation in SBP, individual and neighborhood predictors of SBP were analyzed with multilevel linear regression models.[15] To derive parsimonious models, only the individual and neighborhood variables that were associated with SBP were retained in the model.

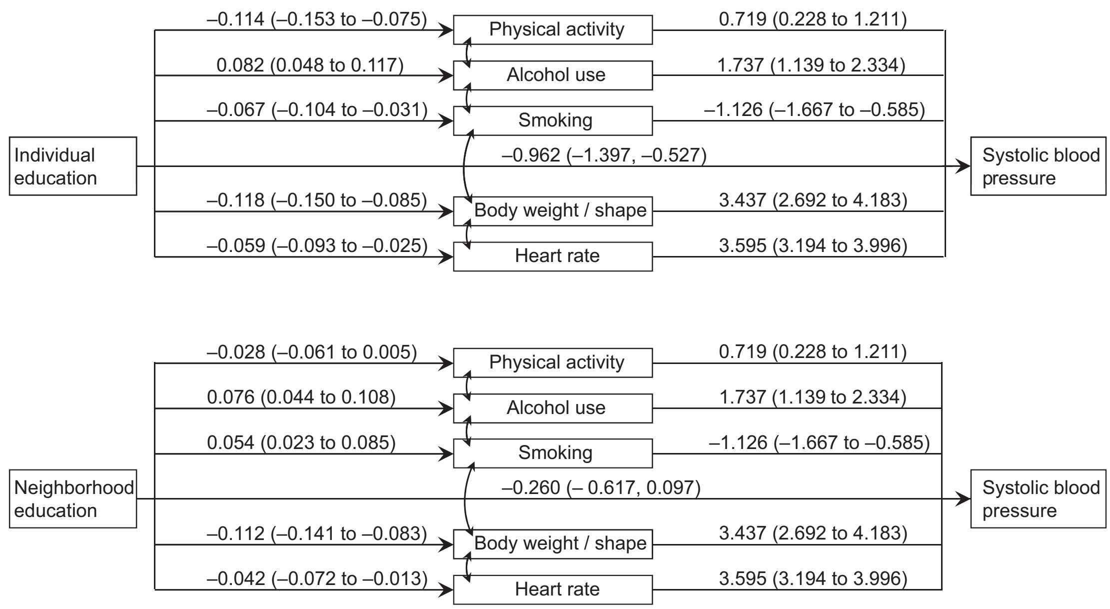

Figure. Graphic display of the estimated path analysis model. The 6 regression equations, with SBP and each of the potential mediators as the outcomes, are represented by single-headed arrows. Double-headed arrows refer to the estimated covariances between residuals of the models for each mediator as the outcome. The product of the coefficients along a compound path reflects the weight of that path. Figures in parentheses refer to 95% CIs.

Mediation Analyses

The individual risk factors of hypertension were then further entered into the model. Our aim was to assess the extent to which risk factors of hypertension mediated, that is, explained, the associations between individual/neighborhood socioeconomic variables and SBP. Family history of hypertension was considered not to be a plausible mediator between the participant's individual and neighborhood education level and his/her blood pressure, but was entered into the model for adjustment. Our aim was to rank risk factors of hypertension according to their importance in mediating the associations between individual/neighborhood socioeconomic variables and SBP.

We used the path analysis model described in the Figure to approximately quantify the share of the associations between individual/neighborhood socioeconomic variables and SBP that was statistically explained by each of the mediating risk factors. When required assumptions are met,[16] this approach allows one to decompose an association (between individual/neighborhood socioeconomic factors and SBP) into direct and indirect effects (through each of the mediating risk factors).[17]

In these mediation analyses, individual and neighborhood socioeconomic variables were incorporated as ordinal variables. As explained in the online Appendix (please see online Data Supplement), all of the potential mediating risk factors were introduced as binary or ordinal variables to ensure homogeneity in the definition of mediators (see coding in footnotes to Table 2). Because body mass index and waist circumference were too correlated (Pearson correlation among the 3-category ordinal variables: 0.69; $P<0.0001$) to be introduced into the path analysis model simultaneously, we constructed a 9-category ordinal variable combining these factors (see the online Data Supplement).

All of the regression equations involved in the path analysis model (for SBP and all of the mediating risk factors) were adjusted for individual sociodemographic variables, antihypertensive medication use, and family history of hypertension. Technical details pertaining to the model, interpretation of the coefficients, and assumptions required for a valid decomposition into direct and indirect effects[16] are described in the online Appendix.

Results

In our sample, mean SBP was 127.6 mm Hg (95% CI: 127.2 to 128.0 mm Hg), mean body mass index was 25.3 kg/m^2 (95% CI: 25.2 to 25.5 kg/m^2), and mean resting heart rate was 62.2 bpm (95% CI: 62.0 to 62.5 bpm). Overall, 11.1% of the participants were on antihypertensive medication and 3.7% were on β-blockers. Details of the distribution of individual and neighborhood variables and SBP levels according to these variables are reported in the online Appendix. For example, mean age-adjusted SBP was 126.1, 127.3, 129.9, and 131.8 mm Hg and 126.0, 126.6, 128.0, and 130.4 mm Hg in the 4 categories of decreasing individual and neighborhood education, respectively.

The individual and neighborhood variables that were associated with SBP after mutual adjustment are shown in Table 1. A higher SBP was observed among individuals who did not own their dwelling and among people born in a low human development country. SBP was lower among the unemployed. However, individual socioeconomic influences were dominated by the strong dose-response increase in SBP with decreasing education level of participants. The other individual socioeconomic variables were not associated with SBP (SBP tended to increase with decreasing mother's education, but the association was not statistically significant after adjustment).

Regarding neighborhood influences, SBP showed a much stronger pattern of association with neighborhood education than with the other neighborhood variables. After controlling for individual covariates, SBP regularly increased with decreasing neighborhood education (Table 1). Once neighborhood education was introduced into the model, the other neighborhood variables were not associated with SBP.

Individual risk factors for high blood pressure were then introduced into the model (Table 1, second column). Factors associated with a higher SBP included family history of hypertension, alcohol consumption, overweight or obesity, high waist circumference, and a medium or high heart rate.

Table 1. Associations Between Individual and Neighborhood Sociodemographic Variables and SBP, Without (Model 1) and With (Model 2) Additional Adjustment for Risk Factors for High Blood Pressure, Estimated From Multilevel Models (RECORD Cohort Study, n=5941)

	Model 1		Model 2	
Individual/Neighborhood Variables	β	95% CI	β	95% CI
Age (1-y increase)	+0.46	(+0.41 to +0.51)	+0.39	(+0.34 to +0.43)
Male (vs female)	+4.77	(+3.92 to +5.63)	+4.94	(+4.09 to +5.80)
Antihypertensive medication use	+9.80	(+8.49 to +11.11)	+6.98	(+5.71 to +8.25)
Individual education (vs high)				
Mid-high	+1.06	(+0.08 to +2.05)	+0.76	(−0.17 to +1.69)
Mid-low	+2.64	(+1.52 to +3.76)	+1.94	(+0.88 to +3.01)
Low	+3.96	(+2.22 to +5.71)	+2.76	(+1.09 to +4.43)
Employment status (vs employed)				
Unemployed	−2.41	(−3.61 to −1.21)	−1.84	(−2.97 to −0.70)
Retired	+0.93	(−0.50 to +2.36)	+1.06	(−0.30 to +2.41)
Nonownership of dwelling	+1.87	(+1.00 to +2.74)	+1.26	(+0.43 to +2.09)
Low human development of country of birth (vs medium or high)	+4.45	(+2.37 to +6.54)	+3.95	(+1.98 to +5.92)
Neighborhood education (vs high)				
Mid-high	+0.45	(−0.71 to +1.60)	+0.08	(−1.00 to +1.16)
Mid-low	+1.29	(+0.12 to +2.47)	+0.73	(−0.37 to +1.83)
Low	+2.39	(+1.16 to +3.62)	+0.86	(−0.30 to +2.02)
Family history of hypertension			+2.71	(+1.91 to +3.52)
Regular physical activity			+0.95	(+0.18 to +1.71)
Alcohol consumption (vs nondrinker)				
Former drinker			+0.97	(−1.06 to +3.00)
Light drinker			+2.34	(+1.11 to +3.58)
Drinker			+6.16	(+4.36 to +7.96)
Smoking (vs never smoker)				
Former smoker			−1.37	(−2.27 to −0.46)
Smoker			−1.98	(−2.98 to −0.99)
Body mass index (vs normal)				
Overweight			+3.74	(+2.80 to +4.67)
Obese			+7.90	(+6.12 to +9.68)
Waist circumference (vs ideal)				
High			+1.34	(+0.26 to +2.41)
Very high			+2.74	(+1.02 to +4.45)
Resting heart rate (vs low)				
Medium			+4.03	(+3.20 to +4.87)
High			+8.90	(+7.88 to +9.93)

All of the effects in the same column are adjusted for each other.

As in other studies where blood pressure was also measured after a tobacco-free interval,[18] smoking was associated with a lower SBP. Regular physical activity, which included activity at work, was associated with a slightly higher SBP. Interestingly, associations between individual or neighborhood education and SBP were drastically reduced after adjustment for risk factors. The association with individual education persisted after adjustment, whereas that with neighborhood education was reduced to nonsignificance.

The path analysis model depicted in the Figure was used to assess the role played by possible mediating risk factors in explaining associations between individual/neighborhood education and SBP (please see the online Data Supplement for interpretation of the coefficients). As shown in the left part of Figure, a high individual education was associated with excessive alcohol use, lower odds of being physically active (including activity at work), lower odds of smoking and obesity, and with a lower resting heart rate. High neighborhood education was associated with alcohol use, smoking, lower odds of obesity, and lower resting heart rate. Indirect effects of individual/neighborhood education on SBP through each of these mediators, expressed in millimeters of mercury, are shown in the online Appendix. Only the main indirect effects

Table 2. Proportion of the Associations Between Individual/Neighborhood Education and SBP Mediated by Each of the Risk Factors of High Blood Pressure Determined From the Path Analysis Model in the Figure (RECORD Cohort Study, n=5941)

Potential Mediating Risk Factor	Percentage of the Association Between Individual Education and SBP Attributable to Each Mediator, % (95% CI)	Percentage of the Association Between Neighborhood Education and SBP Attributable to Each Mediator, % (95% CI)
Regular physical activity	5.7 (1.0 to 10.4)	2.7 (−1.1 to 6.6)
Alcohol consumption	−9.9 (−16.2 to −3.7)	−17.7 (−30.9 to −4.4)
Smoking	−5.3 (−9.6 to −0.9)	8.2 (0.9 to 15.4)
Body mass index/waist circumference	28.0 (16.3 to 39.7)	51.6 (24.5 to 78.6)
Resting heart rate	14.7 (6.1 to 23.3)	20.4 (4.6 to 36.2)

Physical activity was coded as a binary variable. Alcohol consumption was coded as a 4-category ordinal variable (never drinker, former drinker, light drinker, and heavy drinker). Smoking was coded as a 3-category ordinal variable (never smoker, former smoker, and smoker). Body mass index/waist circumference was coded as a 9-category ordinal variable. Heart rate was coded as a 3-category ordinal variable.

("explaining" ≥10% of the associations of interest as reported in Table 2) are commented on below.

As shown in the Figure, alcohol consumption increased (rather than decreased) with both individual and neighborhood education. Therefore, alcohol consumption tended to mask rather than explain the associations between individual/neighborhood education and SBP (Table 2).

The main indirect effects of education level on SBP through mediating risk factors involved body mass index/waist circumference and heart rate (Table 2). Adding validity to the finding, these 2 factors were the main mediators for the effects of both individual education and neighborhood education. Because decreased individual and neighborhood education were associated with a higher body mass index/waist circumference and resting heart rate, the indirect effects of individual/neighborhood education on SBP through these 2 risk factors significantly contributed to the higher SBP observed in low-education individuals and low-education neighborhoods.

According to the proportion of the associations explained by each of the risk factors (Table 2), body mass index/waist circumference was, by far, the most significant contributor to the relationships between education and SBP: the corresponding indirect effects represented 28.0% (95% CI: 16.3% to 39.7%) of the individual education-SBP association and 51.6% (95% CI: 24.5% to 78.6%) of the neighborhood education-SBP association. Resting heart rate was the second contributor, accounting for ≈14.7% (95% CI: 6.1% to 23.3%) of the association of SBP with individual education and 20.4% (95% CI: 4.6% to 36.2%) of its association with neighborhood education.

As shown in the Figure, after accounting for all of the indirect effects, the direct (residual) association between neighborhood education and SBP was no longer statistically significant, but the association persisted between individual education and SBP.

Discussion

We found that a decrease in both individual education and neighborhood education was independently associated with a nonnegligible and regular increase in SBP. However, the most innovative aspect of our study was our analyses, which identified body mass index/waist circumference and resting heart rate as the most important intermediate variables contributing to these associations.

Strengths of the present study include meticulous geocoding of the participants, the large study territory that allowed comparison of diverse neighborhoods, the fact that both individual and neighborhood socioeconomic variables were taken into consideration, and the multilevel path analysis framework[2] implemented to investigate mediating pathways in the education-SBP associations. The primary study limitation is the use of cross-sectional data, which did not enable us to confirm that the temporal sequence of phenomena was coherent with the mediation hypothesis (individual/neighborhood education → risk factors of hypertension → SBP).

Associations Between Neighborhood Education and Blood Pressure

Compared to physical inactivity or obesity,[6] few studies have investigated relationships between neighborhood socioeconomic characteristics and blood pressure.[2–5] In the present study, comparing 3 socioeconomic variables (education, income, and dwelling values), only neighborhood education was independently related to SBP, which is consistent with previous findings established at the individual level.[19] It is tempting to speculate that a reason why this particular socioeconomic variable emerged as a predictor of blood pressure is that a high neighborhood education level is associated with health norms and knowledge that promote healthy behavior in terms of diet, physical activity, and healthcare use. However, because of the strong correlation between neighborhood education and alternative neighborhood socioeconomic factors or other environmental variables, and in the absence of other supporting data, this statement may be excessive. At least it is an interesting hypothesis for future research.

Mechanisms in the Association Between Education and Blood Pressure

An original aspect of our study was the attempt to investigate which, of a number of risk factors of hypertension, intervene as mediating mechanisms in the associations between individual/neighborhood education and SBP (under the hypothesis of the causal diagram in the Figure and the assumptions[16] discussed in the online Appendix). The only other study that examined intermediate processes between neighborhood socioeconomic variables and blood pressure only considered weight status as a mediator,[2] not providing a distinction between the different underlying mediating mechanisms, as we did here.

Strikingly, it was found that the 2 risk factors (of the 5 variables considered) that emerged as the main statistical mediators were the same for the effects of individual education and neighborhood education. Body mass index/waist circumference was by far the main mediating variable,[1] but resting heart rate also had a nonnegligible mediating role.

The fact that a significant part of the association between individual education and blood pressure was mediated by the lower body weight of high educated individuals may be partly because of their more accurate knowledge of health risks associated with obesity and greater motivation to control weight. Also, in additional path analyses reported in the online Appendix, we found that low individual education was associated with perceived stress, which was associated with a higher body mass index/waist circumference, which was, in turn, associated with a higher blood pressure. However, not to mention uncertainties in the causal model involving stress (see Discussion in the online Data Supplement), perceived stress only explained 5% of the mediating role that body weight had in the association between individual education and blood pressure. Similarly, the pathway from "individual education" to "symptoms of depression" to "body mass index/waist circumference" to "SBP" was statistically significant but only accounted for 2.4% of the mediating effect of body weight (see the online Data Supplement).

The large share of the relationship between neighborhood education and SBP that was mediated by body mass index/waist circumference may be interpreted in light of the growing literature showing effects of a number of environmental dimensions on physical activity and dietary behavior.[20,21] A number of mechanisms related to the neighborhood environment, including specific behavioral habits, a more unfavorable food environment, and a weaker potential for active living in disadvantaged neighborhoods, may increase blood pressure through body weight and shape modification.

Resting heart rate statistically explained a nonnegligible share of the individual/neighborhood education-SBP associations. We may be tempted to hypothesize that part of the mediating effect of heart rate is attributable to the effects of stress on heart rate. Certain authors[5] have interpreted associations between individual or neighborhood socioeconomic characteristics and heart rate in relation to the chronic stressors associated with poverty or life conditions of disadvantaged neighborhoods (eg, crowding, noise, unemployment, crime, and violence). Therefore, given reported effects of heart rate on hypertension incidence,[22] it is possible that part of the effect of individual/neighborhood education on SBP through heart rate reflects the greater exposure to economic and environmental stressors in high-deprivation neighborhoods. However, additional analyses reported in the online Appendix indicated that perceived stress was not associated with SBP and that perceived stress played no part in the nonnegligible mediating effect that resting heart rate had in the associations between individual/neighborhood education and blood pressure. Longitudinal studies using other measures of psychological stress are needed to explore this issue further.

Although heart rate was assessed after a sufficient resting period, we cannot exclude the possibility that the higher heart rate associated with low education reflected a temporary increase in heart rate when visiting the health center (white coat syndrome). Moreover, we could not verify whether heart rate really intervened as a mediator between individual/neighborhood education and blood pressure or whether 1 or more factors, including sympathetic activity, were in fact influencing both heart rate and blood pressure. Thus, whereas our study allows one to generate innovative hypotheses on the mediating role of resting heart rate in socioeconomic effects on blood pressure, its findings will have to be replicated with a longitudinal design in the next stages of the RECORD Cohort Study.

Finally, additional analyses reported at the end of the online Appendix showed that, among hypertensive participants, a high individual or neighborhood education was not associated with awareness of hypertension, antihypertensive medication use, and control of hypertension, making it rather unlikely that these factors contribute to the observed education-blood pressure associations.

Perspectives

From a clinical viewpoint, our study suggests that, after accounting for individual risk factors, socioeconomic characteristics of residential environments were not especially useful for identifying individuals with high blood pressure. However, implications are different from a public health perspective, which would conclude that neighborhood environments affect blood pressure through specific risk factors. In this latter approach, it is critical to disentangle the mechanisms through which neighborhood physical and social environments influence blood pressure (eg, through weight status or heart rate modification) to effectively intervene in reducing sociospatial disparities in blood pressure.[1,7]

Acknowledgments

We thank Alfred Spira, head of the French Institute for Public Health Research, for his advice and support. We are also grateful to Insee, the French National Institute of Statistics and Economic Studies, which provided support for the geocoding of the RECORD participants and allowed us access to relevant geographical data (with particular thanks to Aline Désesquelles, Pascale Breuil, and Jean-Luc Lipatz). We thank Geoconcept for giving us access to the Universal Geocoder software. We are grateful to Paris-Notaries for providing geographical data used in the present analysis. We also thank the Caisse Nationale d'Assurance Maladie des Travailleurs Salariés (France) and the Caisse Primaire d'Assurance Maladie de Paris (France) for helping make this study possible. We are grateful to Alain Weill from Caisse Nationale d'Assurance Maladie des Travailleurs Salariés for his support in merging the healthcare consumption data from the Système d'Information Inter Régimes de l'Assurance Maladie or Federative Information System of Sick Insurance to the RECORD database.

Sources of Funding

As part of the RECORD project, the present work was funded by the National Research Agency (ANR; Health-Environment Program); the Institute for Public Health Research (IReSP); the National Institute for Prevention and Health Education (INPES; Prevention Program 2007); the National Institute of Public Health Surveillance (InVS; Territory and Health Program); the French Ministries of Research and Health (Epidemiologic Cohorts grant 2008); the National Health Insurance Office for Salaried Workers (CNAM-TS); the Ile-de-France Health and Social Affairs Regional Direction (DRASSIF); the Ile-de-France Public Health Regional Group (GRSP); and the Ile-de-France Youth and Sports Regional Direction (DRDJS).

Disclosures

None.

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Online data supplement

INDIVIDUAL/NEIGHBORHOOD SOCIAL FACTORS AND BLOOD PRESSURE IN THE RECORD COHORT STUDY: WHICH RISK FACTORS EXPLAIN THE ASSOCIATIONS?

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Descriptive statistics

Table S1 provided at the end of the present appendix indicates the percentage of participants in each category of the individual sociodemographic variables, individual risk factors, and neighborhood sociodemographic variables considered in the article (first column).

Table S1 (second and third columns) also reports systolic blood pressure (SBP) levels according to the different individual and neighborhood variables. Using simple linear models only adjusted for age, we report age-adjusted mean SBP according to these variables, together with lower and upper 95% confidence limits. Age-adjusted mean SBP was predicted for the average age in the sample (i.e., 50 years of age) from these simple models only considering age as a predictor (one separate model was estimated for each individual or neighborhood variable for which descriptive information on SBP is provided).

Interestingly, differences in age-adjusted SBP were important according to both individual education and neighborhood education, even if slightly greater according to the former.

Statistical methods: description of the path analysis model

Variables considered in the path analysis

In the path analysis (investigating which risk factors mediated associations between individual or neighborhood socioeconomic variables and blood pressure), SBP was taken into account as a continuous variable.

Individual and neighborhood education, retained as the socioeconomic variables of interest, were considered as ordinal variables (coded from 1 to 4). It was also necessary to use ordinal variables rather than continuous variables to express some of the mediating risk factors. For example, we had to rely on categorical variables (ordinal variables) for tobacco and alcohol consumption, in order to distinguish former smokers and former drinkers from never consumers. Tobacco and alcohol consumption were thus defined as ordinal variables distinguishing never consumers, former consumers, and current consumers (with an additional distinction between light consumption and heavy consumption for drinking).

Body mass index and waist circumference were too correlated to be introduced into the path analysis model simultaneously (Pearson correlation between the 3-category ordinal variables = 0.69, $p < 0.0001$). Therefore, we combined them into a single variable. To do this, we predicted SBP based on these two 3-category variables from a model adjusted for all other factors, and used this predicted SBP level (taking 9 different possible values) to construct a 9-category ordinal variable. This ordinal variable which combined information on body mass index and waist circumference was used as a mediating risk factor in the path analysis model.

If all mediating risk factors except one were considered as categorical variables and the last one (resting heart rate) was taken into account as a continuous variable, the comparison of the mediating role of the different risk factors could be distorted. Consequently, to ensure homogeneity in the definition of the different risk factors, all intermediate variables were introduced as ordinal variables or binary variables (see coding in Table 2 footnotes of the main article).

Description of the path analysis model

In the model depicted in Figure 1 (main article), the 6 regression equations were estimated simultaneously. A linear regression model was estimated for SBP. Associations between individual/neighborhood socioeconomic characteristics and the mediating risk factors (defined as binary or ordinal variables) were modeled with probit regression models considering continuous latent variables as the outcomes.[1,2]

In the MPlus path analysis framework, the categorical mediators m are replaced by underlying continuous latent variables m*. For each binary mediator, a threshold is determined so that m = 0 if the continuous latent variable m* is below the threshold and m = 1 if the continuous latent variable is above the threshold. Similar continuous latent variables m* are defined for ordinal mediators m, with two different thresholds for 3-category variables, three different thresholds for 4-category variables, etc. When modeling a pathway like "education → risk factor → SBP" as "x → m → y", the continuous latent variable m* is used both as the outcome in the equation "x → m" and as the explanatory variable in the equation "m → y", enabling us to rely on linear-linear relationships in the path analysis.

All regression equations included a neighborhood-level random effect (multilevel model), and were adjusted for individual sociodemographic variables, antihypertensive medication use, and family history of hypertension. Family history of hypertension was not specified as a mediating risk factor because it reflects a shared risk of hypertension at the family level that is to a large extent defined before an individual's education is completed and well before the individual moves to his/her current neighborhood of residence. However, family history of hypertension was included as an adjustment variable in all regression equations. The equation for SBP was further adjusted for all mediating risk factors. The path analysis model also estimated covariances between the residuals of the probit models for the different mediating risk factors, in order to take into account that common predictors of the risk factors may be left out of the models.

Using MPlus 5.21 to estimate the path analysis model, we were able to derive a 95% confidence interval for the proportion of the associations between individual/neighborhood socioeconomic characteristics and SBP mediated by each risk factor.[2]

Interpretation of the coefficients

Regarding the coefficients on the left side of Figure 1 (main article), for example, the coefficient of –0.112 for the effect of neighborhood education on body mass index/waist circumference indicates that each 1-unit increase in neighborhood education (coded from 1 to 4) is associated with a 0.112 unit decrease in the underlying continuous variable related to body mass index/waist circumference.

Regarding the coefficients on the right side of Figure 1, for example, the coefficient of 3.437 for the effect of body mass index/waist circumference on SBP indicates that each 1-unit increase in the underlying continuous variable associated with body mass index/waist circumference is associated with a 3.4 mmHg increase in SBP.

In the path model, the strength of an indirect path is evaluated by calculating the product of the coefficients along that path. For example, the indirect effect of neighborhood education on SBP through body mass index/waist circumference is $-0.112 \times 3.437 = -0.385$ mmHg. An interpretation of this indirect effect is that each 1-unit increase in neighborhood education (coded from 1 to 4) is associated with a 0.385 mmHg decrease in SBP for that specific part of the effect operating through body mass index/waist circumference. Such indirect effects of individual/neighborhood education on SBP through each of the mediating risk factors (expressed in mmHg) are reported in Table S2 of the present appendix.

Assumptions required to test mediation hypotheses

To reliably decompose an association into direct and indirect effects, some authors[3] have suggested that one needs (i) additivity of effects and linear contrasts; (ii) absence of confounding in the associations between mediators and the outcome; and (iii) absence of individuals for whom the main exposure and mediating risk factors interact to cause the outcome.

As noted above, in MPlus, the first requirement is met when using binary or ordinal mediators as we did by replacing categorical variables by continuous latent variables through probit modeling.[1,2] Regarding the second assumption (absence of confounding as an omnipresent concern in observational epidemiology), we cannot assert that associations between mediating risk factors and SBP were not confounded. Large confounding biases for some of the risk factors but not for others would modify the observed ranking of risk factors according to their role in mediating associations between individual/neighborhood education and SBP. However, the magnitude of confounding may have been reduced by simultaneously considering several risk factors of hypertension.

Finally, an acceptable way to check the third required assumption for a valid decomposition of effects into direct and indirect effects[3,4] is to confirm that associations between individual/neighborhood education and SBP are homogeneous across strata of each of the mediating variables. This assumption was valid for all risk factors.

Also, it is important to keep in mind that our mediation model ignored causal relationships between risk factors by specifying mediators as parallel indirect pathways (see Figure 1, main text) rather than as series of mediators ($x \rightarrow m_1 \rightarrow m_2 \rightarrow y$) as would be necessary for some of them. This model specification is expected to favor the most proximate risk factors compared to the more distal ones.

Indirect effects of individual/neighborhood education on SBP through each of the mediating risk factors of high blood pressure

Table S2 shows the indirect effects of individual/neighborhood education on SBP through each of the mediating risk factors, as estimated from the path analysis model represented in Figure 1 (main text) and described in the previous section of the online appendix. As noted above, these indirect effects through risk factors (determined by calculating the product of the coefficients along each path) are expressed in mmHg.

Clearly, the two main indirect effects contributing to the association between individual education and SBP were operating through body mass index/waist circumference and resting heart rate. Apart from the counterintuitive effect through physical activity (which could be explained by activity at work), no other risk factor significantly contributed to the lower SBP observed in high educated individuals.

Similarly, the indirect effects through body mass index/waist circumference and resting heart rate were the most important in explaining the observed association between neighborhood education and SBP.

Additional results involving refined path analysis models

Hypotheses

In order to clarify the mechanisms, we tested additional hypotheses on the processes involved in the associations between individual/neighborhood education and SBP.

It is common to assume that stress may play a part in the associations between individual/neighborhood socioeconomic status and blood pressure. To address this issue, we tested the following mediation hypotheses using refined path analysis models:

(i) Perceived stress may be a direct mediator in the associations between individual/neighborhood education and SBP, independent of the other risk factors already considered (discussed below as model A).

(ii) As represented in Figure S1 at the end of the present appendix, individual/neighborhood education may be associated with perceived stress, which may be associated with heart rate, which in turn is associated with SBP. A more direct path between individual/neighborhood education, heart rate, and SBP (independent of perceived stress) was also specified, in order to distinguish between mediating effects of heart rate that were or were not due to perceived stress (discussed below as model B).

(iii) As represented in Figure S2, individual/neighborhood education may be associated with perceived stress, which may be associated with body mass index/waist circumference, which in turn is associated with SBP. We also specified a direct path between individual/neighborhood education, body mass index/waist circumference, and SBP (independent of perceived stress), in order to distinguish between mediating effects of body mass index/waist circumference that were or were not due to perceived stress (discussed below as model C).

(iv) Apart from stress, depressive symptoms (through their effect on diet) may also increase body weight, thereby leading to a causal path between social variables and blood pressure. As presented in Figure S3, individual/neighborhood education may be associated with depressive symptoms, which may be associated with body mass index/waist circumference, which in turn is associated with SBP (discussed below as model D).

Statistical analyses

In order to investigate possible mediating effects of stress, we relied on Sheldon Cohen's validated Perceived Stress Scale[5] that allows one to identify individuals who feel overwhelmed by life events and feel that they have no control over the course of their lives. All participants completed the Perceived Stress Scale at baseline. We divided this variable into four categories (0 or 1; 2 or 3; 4–6; and 7–16), and considered it as an ordinal variable.

To identify depressive symptoms, we used Pichot's QD2A,[6] which can be used to detect depressive subjects in a population. Composed of 13 binary items, the test has a good internal consistency. Several studies have demonstrated its empirical validity, as well as its coherence with other depression scales.[6] It has been shown that a score >6 on the QD2A test is strongly associated with a clinical diagnosis of depression. We divided this variable into four categories (0; 1 or 2; 3–6; 7–13), and considered it as an ordinal variable.

Models A, B, C, and D were constructed by adapting the path analysis model considered in the main article and described in the previous section of the online appendix.

Model A was obtained by including an additional mediating variable to the 5 mediating variables already included in the model described in Figure 1 of the main article.

Model B (represented in Figure S1 at the end of the appendix) was derived from model A by specifying an additional arrow between stress and heart rate, in order to examine whether stress had an influence on heart rate and whether stress contributed to the associations between individual/neighborhood education and SBP through its effect on heart rate.

Similarly, model C (represented in Figure S2 at the end of the appendix) was derived from model A by specifying an arrow between stress and body mass index/waist circumference, in order to test whether stress had an influence on body mass index/waist circumference and whether stress contributed to the associations between individual/neighborhood education and SBP through its effect on body mass index/waist circumference.

Model D (represented in Figure S3 at the end of the appendix) resembles to model C, but instead of considering perceived stress it considers depressive symptoms.

Results and their interpretation

The analyses indicated that perceived stress strongly increased with decreasing individual education ($p < 0.001$), but that it only weakly increased with decreasing neighborhood education ($p = 0.071$) after adjustment for individual education and other covariates. Moreover, perceived stress showed absolutely no association with SBP ($p = 0.53$). Accordingly, in model A, perceived stress had no mediating role in the associations between individual/neighborhood education and SBP, i.e., mediated –1% (95% CI: –5%, 3%) of the effect of individual education and 0% (95% CI: –2%, 1%) of the effect of neighborhood education on SBP.

In model B (illustrated in Figure S1), we found that perceived stress had absolutely no effect on resting heart rate ($p = 0.79$). Thus, not surprisingly, perceived stress did not contribute at all to the mediating mechanism between individual/neighborhood education and SBP through heart rate. In this model, resting heart rate mediated 23% (95% CI: 5%, 41%) of the association between neighborhood education and SBP, but no more than 0% (95% CI: –2%, 2%) of this mediating effect was attributable to the pathway through perceived stress.

In model C (represented in Figure S2), we found that perceived stress was significantly associated with a higher body mass index/waist circumference ($p = 0.01$). Accordingly, the specific pathway “individual education → perceived stress → body mass index/waist circumference → SBP” was statistically significant ($p = 0.018$). However, it was of minor importance compared to the more direct pathway “individual education → body mass index/waist circumference → SBP” (not mediated by perceived stress), accounting for only 5% (95% CI: 1%, 9%) of the mediating role that body mass index/waist circumference had in the association between individual education and SBP. By contrast, due to the small effect of neighborhood education on perceived stress, the following pathway was not statistically significant: “neighborhood education → perceived stress → body mass index/waist circumference → SBP” ($p = 0.15$).

In summary, a conclusion may be that perceived stress played a statistically significant but minor role in the association between individual education and SBP, operating through the effect of stress on body weight. However, this conclusion would only hold if the cross-sectional association between stress and body weight was attributable to a causal effect of stress on body weight, which may not be true. Indeed, it may be argued that the stress–body weight association is due to the fact that being overweight or obese is stressful (in reducing life opportunities, in case of a perceived difficulty to loose weight, etc.).

Similarly, in model D (represented in Figure S3), depressive symptoms were significantly associated with a higher body mass index/waist circumference ($p = 0.01$). Accordingly, the specific pathway “individual education → depressive symptoms → body mass index/waist circumference → SBP” was statistically significant ($p = 0.030$). However, this pathway accounted for only 2.4% (95% CI: 0.2%, 4.6%) of the mediating role that body mass index/waist circumference had in the association between individual education and SBP. Moreover, as for perceived stress, the causal relationship hypothesized in Figure S3 between depressive symptoms and body weight may not hold true (the association observed in our data may also be attributable to the depressing effect of obesity).

Additional results on hypertension awareness, treatment, and control rates

Hypotheses

In the present article, our aim was to quantify individual and neighborhood socioeconomic disparities in SBP, and identify some of the factors that may contribute to the observed disparities. We may hypothesize that differences in terms of hypertension awareness, access to treatment, and control of hypertension among hypertensive participants according to individual and neighborhood socioeconomic variables may help explain individual/neighborhood social disparities in blood pressure. Additional analyses were conducted to test these hypotheses.

Population, measures, and methods

These analyses were conducted among the 1666 hypertensive participants, i.e., among those with SBP higher than 140 mmHg or with diastolic blood pressure (DBP) higher than 90 mmHg or being on antihypertensive medication (as defined from reimbursed healthcare utilization during the year prior to study recruitment). Three different outcomes were considered in this specific population: (i) awareness of hypertension (based on the self-report of hypertension in the questionnaire); (ii) being on antihypertensive medication; and (iii) control of hypertension, i.e., having both a SBP below 140 mmHg and a DBP below 90 mmHg (as measured during the examination).

For each of the 3 binary outcomes, we estimated a multilevel logistic regression model which takes into account basic individual and neighborhood sociodemographic variables, i.e., age, gender, marital status, individual education, household income, and neighborhood education.

Results

As shown in Table S3, the odds of hypertension awareness, of being on antihypertensive medication, and of having a controlled hypertension increased with age. Hypertension treatment and hypertension control were slightly less common among males. Individual education and household income were not associated with any of the 3 outcomes.

Neighborhood education showed a pattern of association only with hypertension awareness. However, the association was opposite of what was expected: after adjustment for individual factors, a low neighborhood education was associated with higher odds of hypertension awareness.

Conclusion

Given that hypertension awareness, treatment, and control were not found to be more common in high education groups, there is no support in favor of arguing that these variables contribute to the lower blood pressure levels identified in individuals with a high education and neighborhoods with a high average education.

Associations between individual/neighborhood sociodemographic variables and diastolic blood pressure, and related path analysis

Objectives

All the analyses reported in the main article for SBP were replicated for DBP. Our aim was to investigate associations between individual/neighborhood sociodemographic characteristics and DBP and examine whether these associations were mediated by specific risk factors of hypertension.

Methods

We used the same individual and neighborhood sociodemographic variables and the same risk factor variables as those employed in the main article, and followed the very same analytic strategy (see Methods section in the main text).

Results

As shown in Table S4 (first column), the individual sociodemographic variables associated with DBP were slightly different from those associated with SBP. Dwelling ownership was not associated with DBP, but a lower mother's education level was associated with a higher DBP. Self-reported financial strain was also independently associated with a higher DBP. Just as for SBP, a higher DBP was observed among participants who were born in countries with a low degree of human development. We also noted a strong and regular increase in DBP with decreasing individual education. As shown in Table S4, after adjustment for individual sociodemographic variables, DBP also increased with decreasing education level of the neighborhood of residence.

The individual risk factors for hypertension were then introduced into the model (Table S4, second column). As for SBP, the associations between individual/neighborhood education and DBP were drastically reduced after adjustment (the association between neighborhood education and DBP was no longer significant).

Finally, we estimated a path analysis model for DBP which was similar to the model used for SBP (see Figure 1 of the main text). As shown in Table S5, body mass index/waist circumference and resting heart rate clearly made the most significant contribution to the associations between individual/neighborhood education and DBP.

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Table S1. Percentage of participants in each category of the individual or neighborhood variables, and age-adjusted mean systolic blood pressure (SBP) according to individual and neighborhood characteristics, RECORD Cohort Study, n = 5941

Individual/neighborhood variables	% of participants	Age-adjusted mean SBP in mmHg	95% CI
Individual sociodemographic characteristics			
Gender			
Male	66%	129.2	(128.7 to 129.7)
Female	34%	124.9	(124.2 to 125.5)
Marital status			
Living alone	29%	128.1	(127.3 to 128.9)
Married or cohabiting	71%	127.5	(127.1 to 128.0)
Individual education			
Low	7%	131.8	(130.2 to 133.3)
Mid-low	23%	129.9	(129.0 to 130.7)
Mid-high	30%	127.3	(126.6 to 128.1)
High	40%	126.1	(125.5 to 126.8)
Parental education			
Low	30%	128.7	(128.0 to 129.5)
Medium	40%	128.0	(127.3 to 128.6)
High	31%	126.1	(125.3 to 126.8)
Mother's education			
Primary	43%	129.0	(128.3 to 129.6)
Secondary	41%	127.1	(126.5 to 127.7)
Tertiary	16%	125.5	(124.5 to 126.6)
Father's education			
Primary	35%	128.6	(127.9 to 129.3)
Secondary	33%	127.7	(127.0 to 128.4)
Tertiary	32%	126.4	(125.6 to 127.1)
Occupation			
Blue collar worker	10%	132.2	(130.8 to 133.5)
Low white collar worker	6%	128.0	(127.4 to 128.7)
Intermediate occupation	39%	127.9	(126.3 to 129.6)
High white collar worker	45%	126.7	(126.1 to 127.3)
Employment status			
Employed	70%	127.9	(127.3 to 128.4)
Unemployed	14%	125.9	(124.7 to 127.0)
Retired	17%	–	
Household income			
Low	21%	129.7	(128.8 to 130.6)
Mid-low	25%	128.2	(127.4 to 129.0)
Mid-high	24%	126.3	(125.5 to 127.1)
High	29%	127.1	(126.3 to 127.9)
Self-reported financial strain			
Yes	15%	130.0	(128.9 to 131.0)
No	85%	127.3	(126.9 to 127.8)
Dwelling ownership			
Ownership	57%	126.4	(125.9 to 127.0)
Non-ownership	43%	129.4	(128.8 to 130.1)
Human development of country of birth			
Low	4%	134.3	(132.2 to 136.3)
Medium or high	96%	127.5	(127.0 to 127.9)

Table S1. Continued

Individual/neighborhood variables	%	Age-adjusted SBP	95% CI
Individual treatment and risk factors			
Antihypertensive medication use			
Yes	11%	137.0	(135.7 to 138.2)
No	89%	126.5	(126.1 to 127.0)
Family history of hypertension			
Yes	35%	130.0	(129.3 to 130.7)
No	65%	126.5	(126.0 to 127.0)
Regular physical activity			
Yes	44%	128.0	(127.4 to 128.6)
No	56%	127.5	(126.9 to 128.0)
Alcohol consumption			
Never drinker	11%	127.1	(125.9 to 128.3)
Former drinker	5%	128.4	(126.6 to 130.3)
Light drinker	76%	127.3	(126.8 to 127.8)
Drinker	8%	132.2	(130.8 to 133.7)
Smoking			
Never smoker	50%	128.2	(127.6 to 128.7)
Former smoker	28%	127.7	(126.9 to 128.4)
Smoker	21%	126.8	(125.9 to 127.7)
Body mass index			
Ideal weight	50%	123.7	(123.2 to 124.3)
Overweight	38%	130.0	(129.4 to 130.6)
Obese	12%	137.7	(136.5 to 138.9)
Waist circumference			
Ideal	67%	125.3	(124.8 to 125.8)
High	21%	130.6	(129.7 to 131.4)
Very high	12%	136.3	(135.1 to 137.5)
Resting heart rate			
Low	41%	123.8	(123.2 to 124.5)
Medium	39%	128.5	(127.8 to 129.1)
High	20%	134.2	(133.3 to 135.1)
Neighborhood characteristics			
Neighborhood education			
Low	25%	130.4	(129.6 to 131.2)
Mid-low	25%	128.0	(127.2 to 128.8)
Mid-high	25%	126.6	(125.8 to 127.4)
High	25%	126.0	(125.1 to 126.8)
Neighborhood median income			
Low	25%	129.7	(128.8 to 130.5)
Mid-low	25%	128.2	(127.4 to 129.0)
Mid-high	25%	126.5	(125.6 to 127.3)
High	25%	126.6	(125.7 to 127.4)
Neighborhood dwelling values			
Low	25%	129.0	(128.1 to 129.8)
Mid-low	25%	128.1	(127.3 to 128.9)
Mid-high	25%	127.5	(126.7 to 128.3)
High	25%	126.3	(125.5 to 127.2)

Table S2. Magnitude of the indirect effects of individual/neighborhood education on systolic blood pressure (SBP) through each of the mediating risk factors (expressed in mmHg), determined from the path analysis model in Figure 1 of the main article, RECORD Cohort Study, n = 5941

Potential mediating risk factor	Indirect effect of individual education on SBP through each mediator (in mmHg)		Indirect effect of neighborhood education on SBP through each mediator (in mmHg)	
	β	95% CI	β	95% CI
Regular physical activity	–0.082	(–0.145 to –0.019)	–0.020	(–0.048 to 0.007)
Alcohol consumption	0.143	(0.068 to 0.218)	0.132	(0.061 to 0.203)
Smoking	0.076	(0.020 to 0.132)	–0.061	(–0.107 to –0.015)
Body mass index/waist circumference	–0.404	(–0.546 to –0.262)	–0.385	(–0.510 to –0.261)
Resting heart rate	–0.212	(–0.335 to –0.089)	–0.152	(–0.261 to –0.044)

Table S3. Individual and neighborhood sociodemographic characteristics associated with (i) awareness of hypertension, (ii) being on antihypertensive medication, and (iii) having systolic and diastolic blood pressure below 140–90 mmHg, from multilevel logistic regression models estimated among hypertensive subjects (all effects in the same column are adjusted for each other, results reported as odds ratios [OR] and 95% confidence intervals [CI]), RECORD Cohort Study, n = 1666

	Hypertension awareness	Hypertension treatment	Hypertension control
Individual/neighborhood variables	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age (1-year increase)	1.03 (1.02 to 1.04)	1.05 (1.04 to 1.06)	1.02 (1.00 to 1.03)
Male (vs. female)	0.84 (0.67 to 1.04)	0.79 (0.63 to 0.99)	0.63 (0.48 to 0.83)
Living alone (vs. married/cohabiting)	1.18 (0.93 to 1.48)	0.92 (0.73 to 1.16)	0.81 (0.60 to 1.07)
Individual education (vs. high)			
Mid-high	0.97 (0.74 to 1.27)	1.03 (0.78 to 1.35)	0.83 (0.60 to 1.16)
Mid-low	0.86 (0.65 to 1.15)	0.92 (0.69 to 1.23)	0.92 (0.65 to 1.30)
Low	0.78 (0.51 to 1.20)	0.84 (0.55 to 1.30)	0.78 (0.45 to 1.34)
Household income (vs. high)			
Mid-high	0.92 (0.68 to 1.24)	0.92 (0.68 to 1.24)	0.91 (0.64 to 1.28)
Mid-low	1.00 (0.74 to 1.37)	0.82 (0.60 to 1.12)	0.67 (0.46 to 0.98)
Low	0.97 (0.70 to 1.35)	1.06 (0.76 to 1.47)	0.77 (0.52 to 1.15)
Neighborhood education (vs. high)			
Mid-high	1.19 (0.88 to 1.61)	0.92 (0.68 to 1.24)	0.88 (0.62 to 1.26)
Mid-low	1.20 (0.88 to 1.63)	1.04 (0.76 to 1.41)	0.88 (0.61 to 1.28)
Low	1.68 (1.22 to 2.30)	1.28 (0.93 to 1.75)	0.89 (0.60 to 1.30)

Table S4. Associations between individual and neighborhood sociodemographic variables and diastolic blood pressure, without (model 1) and with (model 2) additional adjustment for risk factors for high blood pressure, estimated from multilevel models (all effects in the same column are adjusted for each other), RECORD Cohort Study, n = 5941

	Model 1		Model 2	
Individual/neighborhood variables	β	95% CI	β	95% CI
Age (1-year increase)	+0.26	(+0.23 to +0.29)	+0.21	(+0.19 to +0.24)
Male (vs. female)	+4.00	(+3.46 to +4.55)	+4.01	(+3.48 to +4.55)
Antihypertensive medication use	+4.61	(+3.77 to +5.44)	+2.88	(+2.09 to +3.67)
Individual education (vs. high)				
Mid-high	+0.69	(+0.06 to +1.32)	+0.42	(–0.17 to +1.00)
Mid-low	+1.16	(+0.43 to +1.90)	+0.73	(+0.05 to +1.41)
Low	+1.97	(+0.84 to +3.10)	+1.16	(+0.11 to +2.21)
Mother's education (vs. high)				
Medium	+0.49	(–0.27 to +1.25)	+0.19	(–0.51 to +0.89)
Low	+0.90	(+0.09 to +1.72)	+0.55	(–0.21 to +1.30)
Employment status (vs. employed)				
Unemployed	–1.56	(–2.33 to –0.78)	–1.12	(–1.84 to –0.41)
Retired	–3.45	(–4.36 to –2.54)	–3.20	(–4.04 to –2.36)
Financial strain (vs. not)	+1.10	(+0.34 to +1.85)	+0.55	(–0.16 to +1.25)
Low human development of country of birth (vs. medium or high)	+2.71	(+1.37 to +4.04)	+2.55	(+1.32 to +3.78)
Neighborhood education (vs.high)				
Mid-high	+0.48	(–0.23 to +1.20)	+0.28	(–0.38 to +0.93)
Mid-low	+0.56	(–0.17 to +1.30)	+0.26	(–0.41 to +0.93)
Low	+1.14	(+0.36 to +1.91)	+0.29	(+0.43 to +1.01)
Family history of hypertension			+1.51	(+1.01 to +2.01)
Regular physical activity			+0.35	(–0.13 to +0.82)
Alcohol consumption (vs. nondrinker)				
Former drinker			+0.90	(–0.36 to +2.16)
Light drinker			+1.79	(+1.02 to +2.56)
Drinker			+4.51	(+3.39 to +5.62)
Smoking (vs. never smoker)				
Former smoker			–0.13	(–0.69 to +0.43)
Smoker			–0.75	(–1.37 to –0.12)
Body mass index (vs. normal)				
Overweight			+2.65	(+2.07 to +3.23)
Obese			+4.87	(+3.76 to +5.98)
Waist circumference (vs. ideal)				
High			+0.52	(–0.14 to +1.19)
Very high			+0.93	(–0.13 to +2.00)
Resting heart rate (vs. low)				
Medium			+3.91	(+3.40 to +4.43)
High			+8.11	(+7.47 to +8.74)

Table S5. Proportion of the associations between individual/neighborhood education and diastolic blood pressure (DBP) mediated by each of the risk factors of high blood pressure,* RECORD Cohort Study, n = 5941

Potential mediating risk factor	% of the association between individual education and DBP attributable to each mediator		% of the association between neighborhood education and DBP attributable to each mediator	
Regular physical activity	4.3%	(–0.5% to 9.2%)	1.7%	(–1.8% to 5.2%)
Alcohol consumption	–13.3%	(–22.3% to –4.2%)	–23.0%	(–44.3% to –1.7%)
Smoking	–4.4%	(–9.0% to 0.2%)	6.1%	(–1.1% to 13.3%)
Body mass index/waist circumference	26.8%	(14.5% to 39.0%)	57.2%	(15.6% to 98.8%)
Resting heart rate	28.5%	(12.2% to 44.9%)	37.2%	(5.2% to 69.1%)

*Physical activity was coded as a binary variable. Alcohol consumption was coded as a 4-category ordinal variable (never drinker, former drinker, light drinker, and heavy drinker). Smoking was coded as a 3-category ordinal variable (never smoker, former smoker, smoker). Body mass index/waist circumference was coded as a 9-category ordinal variable. Heart rate was coded as a 3-category ordinal variable.

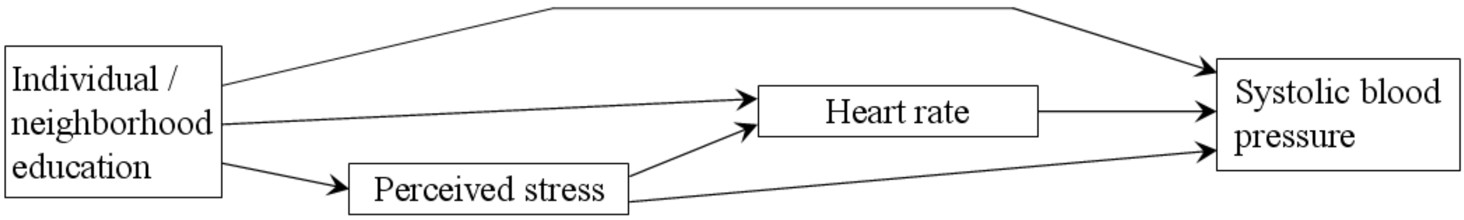

Figure S1. Model depicting a hypothesized mediating role of perceived stress as an antecedent of resting heart rate in the association between individual/neighborhood education and systolic blood pressure (model B)

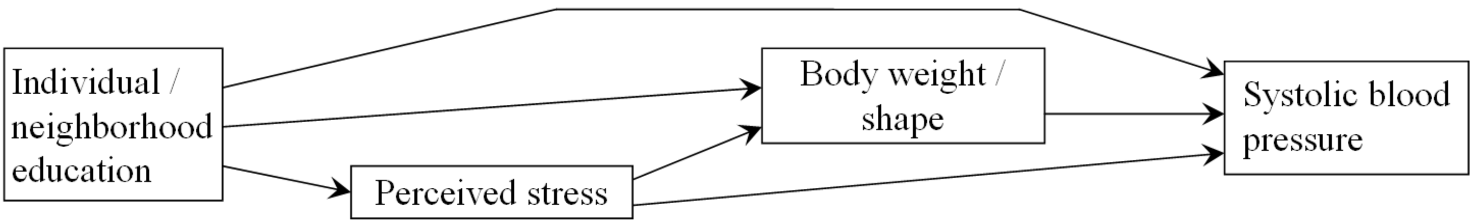

Figure S2. Model depicting a hypothesized mediating role of perceived stress as an antecedent of body mass index/waist circumference in the association between individual/neighborhood education and systolic blood pressure (model C)

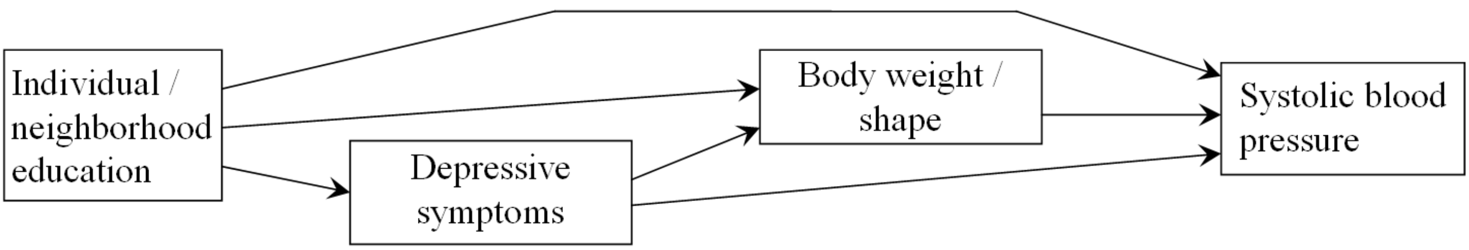

Figure S3. Model depicting a hypothesized mediating role of depressive symptoms as an antecedent of body mass index/waist circumference in the association between individual/neighborhood education and systolic blood pressure (model D)