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End stage renal disease risk and neighbourhood deprivation: A nationwide cohort study in Sweden

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Abstract

Background—Chronic kidney disease has been associated with socioeconomic disparities and neighbourhood deprivation. We aimed to determine whether there is an association between neighbourhood deprivation and end stage renal disease (ESRD), and whether this association is independent of individual-level sociodemographic factors and comorbidities.

Methods—National Swedish data registers were used. The entire Swedish population aged 20–69 years was followed from January 1, 2001 until December 31, 2010. Data were analysed by multilevel logistic regression, with individual-level sociodemographic factors (age, marital status, family income, education level, country of birth, urban/rural status, and mobility) and comorbidities at the first level and neighbourhood deprivation at the second level.

Results—Neighbourhood deprivation was significantly associated with ESRD (age-adjusted odds ratio [OR] 1.45, 95% confidence interval [CI] 1.34–1.56 in men and OR 1.59, 95% CI 1.44–1.75 in women). The ORs for ESRD in men and women living in the most deprived neighbourhoods remained significantly increased when adjusted for age and individual-level sociodemographic factors (OR 1.25, 95% CI 1.15–1.35 in men and OR 1.30, 95% CI 1.17–1.44 in women). In the full model, which took account of sociodemographic factors and comorbidities, the ORs for ESRD remained significantly increased (OR 1.17, 95% CI 1.07–1.27 in men and OR 1.18, 95% CI 1.06–1.31 in women).

Conclusion—Neighbourhood deprivation is independently associated with ESRD in both men and women irrespective of individual-level sociodemographic factors and comorbidities.

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Conflict of interests

No conflict of interest exists and all authors had full access to all the data used in the study and take full responsibility for the decision to submit the manuscript for publication.

Keywords

Neighbourhood deprivation; Socioeconomic factors; End stage renal disease; Risk factors

1. Introduction

Chronic kidney disease (CKD) is a worldwide health problem associated with poor outcomes, high costs, and increased risk of cardiovascular mortality and morbidity [1]. Factors associated with CKD are old age, diabetes mellitus, hypertension, obesity, cardiovascular disease (CVD), ethnicity, family history, and socioeconomic status (SES) [2,3]. Individual-level SES, such as household income, education level, wealth, and occupation, has been associated with lower levels of glomerular filtration [4–8]. In addition to individual-level SES, neighbourhood-level factors may also increase the risk of CKD [9–16]. However, few studies have determined whether neighbourhood deprivation is a risk factor for end stage renal disease (ESRD), independent of individual-level sociodemographic factors, including SES, and comorbidities. In the Atherosclerosis Risk in Communities (ARIC) study only white men had an independent increased risk of progressive CKD in lower SES neighbourhoods [13]. White women, black women, and black men living in lower SES neighbourhoods had no increased risk of CKD compared to their counterparts in higher SES neighbourhoods [13]. In a study by McClellan et al., household but not community poverty was independently associated with CKD [17]. In US people aged above 65 years a significant association was found between living in a poor neighbourhood and CKD, independent of individual-level SES, lifestyle factors, diabetes, and hypertension [18]. In the ARIC study of life-course socioeconomic conditions, after adjustment for diabetes and hypertension, individual-level SES was independently associated with CKD, but neighbourhood-level SES was not [19].

These studies suggest that the associations of individual-level SES and neighbourhood-level SES with CKD and ESRD are complex. Moreover, it is not clear whether comorbidities influence these associations. We aimed to determine, in a large nationwide study, whether there is an association between neighbourhood deprivation and ESRD, and whether this association is independent of individual-level socio-demographic factors, including SES (age, marital status, family income, education level, country of birth, urban/rural status, and mobility) and comorbidities.

2. Methods

2.1. Study design

Data used in this study represent information on all individuals registered as residents of Sweden and aged between 20 and 69 years at the start of the follow-up (January 1, 2001). The data included individual-level information on age, sex, education, occupation, geographic region of residence, hospital diagnoses, and dates of hospital admissions in Sweden, as well as date of emigration, and date and cause of death. The data sources were several national Swedish data registers, including the Swedish National Population and Housing Census, the Total Population Register, the Multi-Generation Register, the Swedish Cancer Registry, and the Swedish Hospital Discharge Register and Outpatient Register, and

were provided to us by Statistics Sweden (the statistics bureau owned by the Swedish government) and the National Board of Health and Welfare [20–22]. The dataset includes ESRD events for the entire population, as well as information on individual-level SES and neighbourhood-level SES [23–25]. We used the main diagnoses of ESRD recorded in the Hospital Discharge Register and Outpatient Register and surgical codes for renal transplantation and dialysis. Linkages were carried out to national census data to obtain data on individual-level SES and geographical region of residence; to the national Cause of Death Register to obtain date of death; and to the Migration Register to obtain date of immigration or emigration. All linkages were performed using the individual national identification number that is assigned to each person in Sweden for their lifetime. This number was replaced by a serial number in order to ensure anonymity. The follow-up period started on January 1, 2001 and proceeded until diagnosis of ESRD, death, emigration, or the end of the study period (December 31, 2010).

2.2. Outcome (dependent) variable

The outcome variable, ESRD, was based on the 10th revision of the International Classification of Diseases (ICD) or the Classification of Surgical Procedures. ESRD was defined as N18.5 (i.e. CKD stage 5), T82.4, Y84.1, Z49, Z94.0, and Z99.2 (ICD-10 codes for ESRD, dialysis or transplantation), and V9211, V9212, V9200, V9531, V9532, V9507, KAS00, KAS10, KAS20, KAS40, KAS50, KAS60, KAS96, KAS97, JAK10, TJA33, TJA35, and TKA20 (surgical codes for transplantation or dialysis). The frequencies of the different diagnoses for ESRD at presentation are shown in Supplementary Table 1.

2.3. Individual-level variables

The individual-level variables were sex, age at the start of the study, marital status, family income, education level, country of birth, urban/ rural status, mobility, and comorbidities [23–25].

Sex: male or female.

Age ranged from 20 to 69 years and was used as a continuous variable in the models.

Marital status: individuals were classified as married/cohabitating or never married/ widowed/divorced.

Family income by quartile: information on family income in 2001 came from the Total Population Register, which was provided by Statistics Sweden. Income was categorised into quartiles: low income, middle–low income, middle–high income, and high income.

Education level was classified as completion of compulsory school or less (9 years), practical high school or some theoretical high school (10–12 years), and theoretical high school and/or college (>12 years).

Country of birth: Born in 1) Sweden (reference), 2) Finland, 3) Western countries, 4) Eastern European countries, 5) Middle Eastern countries, and 6) other countries.

Urban/rural status: residence in large cities (Stockholm, Gothenburg, and Malmö), middle-sized towns, and small towns/rural areas.

Mobility: length of time lived in neighbourhood, categorised as <5 years (moved) or 5 years (not moved).

Comorbidity was defined as the first diagnosis (main or additional diagnosis) during the follow-up period of: 1) chronic lower respiratory diseases (J40–J49), 2) obesity (E65–E68), 3) alcoholism and alcohol-related liver disease (F10 and K70), 4) hypertension (I10–I15), 5) diabetes mellitus (E10–E14), 6) ischemic heart disease (I20–I25), and 7) acute kidney failure (N17).

2.4. Neighbourhood-level SES

The home addresses of all Swedish individuals have been geocoded to small geographical units that have boundaries defined by homogeneous types of buildings. These neighbourhood areas, called small area market statistics, or SAMS, have an average of 1000 people each and were created by Statistics Sweden. SAMS were used as proxies for neighbourhoods, as in previous research [26,27]. SAMS with fewer than 50 people aged 25–64 were excluded ($n = 1053$ SAMS), as were individuals whose addresses could not be geocoded to a neighbourhood area ($n = 83,230$ individuals, 13% of the sample). The final sample included 8372 SAMS.

A summary index was calculated to characterise neighbourhood-level deprivation [28]. The neighbourhood index was based on information on women and men aged 20–64 who lived in the neighbourhood because people in this age group are the most socioeconomically active, that is, as a population group they have a stronger impact on the socioeconomic structure of the neighbourhood than children, younger women and men, and retirees. The neighbourhood index was based on four items: low education level (<10 years of formal education), low income (income from all sources, including that from interest and dividends, defined as less than 50% of the median individual income), unemployment (excluding full-time students, those completing compulsory military service, and early retirees) and receipt of social welfare. The index was categorised into the following three groups (higher scores reflect more deprived neighbourhoods): low neighbourhood deprivation (more than 1 SD below the mean), moderate neighbourhood deprivation (within 1 SD of the mean), and high neighbourhood deprivation (more than 1 SD above the mean) [28].

2.5. Statistical analysis

Age-adjusted cumulative incidence rates were calculated by direct age standardisation using 10-year age groups, with the entire study population of women or men in 2001 as the standard population. Multilevel (hierarchical) logistic regression models with incidence proportions (proportions of adults who became cases among those who entered the study time interval) were used to calculate the outcome variable. Multi-level logistic regression models are a good approximation of Cox proportional hazards models under certain circumstances such as ours (large sample size, low incidence, and risk ratios of moderate size) [29]. The analyses were performed using MLwiN version 2.27. First, a neighbourhood

model including only neighbourhood-level deprivation was created to determine the crude odds of ESRD by level of neighbourhood deprivation. A second model included neighbourhood-level deprivation and age; a third model also included the other individual-level sociodemographic variables (added simultaneously to the model). The full model tested whether neighbourhood-level deprivation was significantly associated with ESRD after adjustment for individual-level sociodemographic factors as well as comorbidity [30]. In the Atherosclerosis Risk in Communities (ARIC) study, white men but not women had an independent increased risk of progressive CKD in lower SES neighbourhoods [13]. Men and women were therefore analysed in separate models. Interaction tests (for both men and women) examined whether the effects of neighbourhood-level deprivation on ESRD rates differed across individual-level SES (income and education) categories, that is, they tested for effect modification. Collinearity was not a problem. There was a low degree of correlation between the factors included in the models.

Random effects: the between-neighbourhood variance was estimated both with and without a random intercept. It was regarded to be significant if it was larger than 1.96 times the standard error.

3. Ethical considerations

The Ethics Committee of Lund University, Sweden approved this study.

4. Results

4.1. Basic population characteristics

The study population consisted of 5,593,516 individuals. Table 1 shows baseline population characteristics in the year 2001. Of the total population, 1,301,351 (23%), 3,370,070 (60%), and 922,095 individuals (17%) lived in low-, moderate-, and high-deprivation neighbourhoods, respectively. During the follow-up period, 12,348 individuals were diagnosed with ESRD. The age-adjusted cumulative incidence rate of ESRD increased from 1.8 per 1000 in neighbourhoods with low deprivation to 2.3 per 1000 in neighbourhoods with moderate deprivation and 2.5 per 1000 in neighbourhoods with high deprivation. Similar trends of slight increases in cumulative incidence rates of ESRD with increasing level of neighbourhood-level deprivation were observed across all individual-level sociodemographic categories and comorbidities. Men (2.3 per 1,000 in low deprived neighbourhood) and women (1.3 per 1,000 in low deprived neighbourhood) had different overall cumulative incidence rates of ESRD.

4.2. Neighbourhood deprivation and ESRD in men

Table 2 shows the different models for men. In the crude model, the odds ratio (OR) for ESRD for men living in high- versus low-deprivation neighbourhoods was 1.32 (95% confidence interval [CI] 1.22–1.43). Neighbourhood-level deprivation was significantly associated with ESRD after adjustment for age (model 2) and age plus individual-level sociodemographic variables (model 3), and in the full model (model 4) adjusted for age, individual-level sociodemographics, and comorbidities. The OR for ESRD was high for several comorbidities: 1.28 for chronic lower respiratory diseases, 2.31 for coronary heart

disease, 4.83 for hypertension, 7.32 for diabetes, and 9.35 for acute kidney failure. Age was included as a continuous variable in models 2, 3, and 4. The OR for ESRD increased by 1.05 for every year of increasing age in models 2 and 3. After adjustment for comorbidities, the OR for age was 1.02. Increased ORs for ESRD were noted in the full model (model 4) for men with low educational level or low family incomes, and for men who were never married, widowed, or divorced. The OR was significantly decreased for men living in middle-sized towns or small towns/rural areas compared with those living in large cities. A slightly but significantly decreased OR was also observed for women who had moved within the previous 5 years. Immigrants from Finland had a lower OR for ESRD than native Swedes. No other differences were observed regarding country of birth.

4.3. Neighbourhood deprivation and ESRD in women

Table 3 shows the different models for women. In the crude neighbourhood-level model, the OR for ESRD for women living in high- versus low-deprivation neighbourhoods was 1.51 (95% CI 1.37–1.67). Neighbourhood-level deprivation remained significantly associated with ESRD after adjustment for age (model 2) and age plus the individual-level sociodemographic variables (model 3). In the full model, additionally adjusted for comorbidities, the OR was 1.18 (95% CI 1.06–1.31). Age was included as a continuous variable in models 2, 3, and 4. The OR increased by 1.04 for every year of increasing age in models 2 and 3. After inclusion of comorbidities, the OR for age was 1.02. Increased ORs for ESRD were noted in the full model (model 4) for women with low educational level or middle family income, and for women who were never married, widowed, or divorced. The OR was significantly decreased for women living in small towns/rural areas compared with those living in large cities. A slightly but significantly decreased OR was also observed for women who had moved within the previous 5 years. Finnish women had a lower OR for ESRD than native Swedish women. Otherwise there was no association with country of birth. All included comorbidities except for obesity were significantly associated with ESRD in women. Especially high ORs were noted for diabetes (8.78), acute kidney failure (7.98), and hypertension (4.44).

4.3.1. Subanalysis—Of all the 12,348 cases with ESRD, 950 (7.7%) patients had a first diagnosis of CKD-5 without dialysis or transplantation, 4542 (36.8%) patients were transplanted, and 6856 (55.5%) patients were in dialysis (Supplement Table 1). Sensitivity analysis was also performed for these three groups of ESRD patients. Among men the OR was similar for all three groups Supplement Table 2). The OR in the fully adjusted model was for ESRD patients without dialysis and transplantation 1.16 (95% CI 0.88–1.53), for transplanted ESRD patients 1.21 (95% CI 1.07–1.35), and for ESRD patients in dialysis 1.16 (95% CI 1.03–1.30) (Supplement Table 5). Among women the highest OR was observed for ESRD patients without dialysis and transplantation 1.61 (95% CI 1.12–2.31) (Supplement Table 3). The OR in the fully adjusted model was for transplanted ESRD patients 1.15 (95% CI 1.00–1.34), and the OR for ESRD patients in dialysis was 1.22 (95% CI 1.05–1.43) (Supplement Table 3).

4.4. Sensitivity analysis

ESRD is a heterogeneous group regarding to aetiology. We have therefore also done analysis with exclusion of patients with the following diagnoses: cystic kidney disease (ICD-10 Q61), congenital kidney and urinary tract malformations (Q60, Q62, Q63, Q64), urolithiasis (N20-N23), rare inherited kidney diseases such as Alport's syndrome and Laurence–Moon–Biedl–Bardet syndrome (Q87.8A, Q87.8B), hyperoxaluria (E74.8B), glomerular disease (N00-N08), and tubular interstitial diseases (N10-N16). Totally 3,1% (n = 172055) of the total study population (5593516) was excluded. Among ESRD cases, these diagnoses constituted 46% (n = 5691) of all 12348 ESRD patients. The association between neighbourhood deprivation and ESRD became even stronger for both women and men after the exclusions (Supplement Tables 4 and 5). In the fully adjusted model 4, the OR in highly deprived neighbourhoods was 1.33 (95% CI 1.1.19–1.49) for men and 1.31 (95% CI 1.13–1.51) for women.

5. Discussion

5.1. Principal findings

In this nationwide cohort study, we found an association between neighbourhood deprivation and ESRD, independently of individual-level sociodemographic factors and comorbidities in both men and women. This association remained significant in the full model, which took account of individual-level sociodemographic factors, including SES, and comorbidities. Previous studies have found divergent results regarding the importance of individual-level SES and neighbourhood-level SES in CKD [13,17–19]. The present study is a nationwide study with high coverage and very high statistical power. It confirms that the incidence of ESRD is greater in patients of lower SES [4–19] and that both individual- and neighbourhood-level SES are important regarding the odds of developing ESRD, even after adjustment for comorbidities. However, the OR for ESRD was lower after adjustment for comorbidities, suggesting that the effect of low individual- and neighbourhood-level SES is partially mediated through these conditions.

In the present study only immigrants from Finland had a lower risk of ESRD than individuals born in Sweden (Tables 2 and 3). As this association remained after adjustments in the full model, a genetic cause is possible. No other significant differences were observed regarding country of birth. The present study adds to previous studies indicating that ethnicity may affect the risk of CKD and ESRD [31]. For example, in the USA the risk of ESRD was reportedly increased in blacks, His-panics, and Asians compared to whites [31]. A higher risk for ESRD in blacks compared with other races was also reported in the USRDS Annual Data Report [32].

Individual- and neighbourhood-level SES have been reported to be associated with CKD and ESRD [4–19]. However, the causal pathways between neighbourhood-level SES and poor health outcomes are not fully understood, and several possible mechanisms could lie behind our findings. One possible mediator could be psychological stress [33,34] due to littered and unsafe environments, vandalism, isolation/alienation, and violent crime [35] in deprived neighbourhoods. Additionally, sociocultural norms regarding diet, smoking, and

physical activity could vary between neighbourhoods and affect the health of residents and the risk of disease [36]. For instance, a Swedish study showed that CVD risk factors including physical inactivity, obesity, and smoking were more common among individuals living in deprived neighbourhoods than among those living in affluent neighbourhoods [37].

In Sweden, medical care is provided to all permanent residents, and primary health care clinics and hospitals are equally distributed and located in all types of neighbourhoods [38]. However, the actual number of health care professionals working in primary health care clinics can vary depending on the neighbourhood. This is related to difficulties in recruiting and retaining health care staff in high-deprivation neighbourhoods [39]. The uneven distribution of medical staff across neighbourhoods has also been documented in the UK [40], another country with universal health care.

5.2. Study limitations and strengths

Our study has some limitations. The study is an observational study and causality cannot be established. In studies of neighbourhood effects on health, selective residential mobility—the tendency of individuals to move to neighbourhoods whose characteristics match their individual characteristics (for example, the tendency of individuals with low SES to move to low-SES neighbourhoods)—can cause compositional neighbourhood differences. However, we adjusted for individual-level SES, which may improve our ability to differentiate between compositional and contextual effects on ESRD. There was a low correlation between the individual-level socioeconomic factors and neighbourhood deprivation (<0.2) and both individual-level and neighbourhood-level socioeconomic factors appear to be of importance. Although we adjusted also for mobility we cannot completely disentangle compositional from contextual effects on ESRD. Moreover, we have no data about smoking and body mass index in the study population. Though we adjusted for diagnoses of chronic lower respiratory diseases and obesity, residual bias is likely to exist.

Unfortunately, we have no information on race or ethnicity. However, we have information about country of birth. In models 3 and 4, the results were adjusted for country of birth. Sweden is a country with a highly heterogeneous population; 26% are first- or second-generation immigrants, which makes the results generalizable to other countries. Variations in MYH9 and APOL1 are associated with non-diabetic chronic kidney disease in individuals of African origin [1]. However, only 46,213 persons (0.8%) were born in Africa. In addition, of the 12348 ESRD cases only 0.9% ($n = 109$) cases were born in Africa. Thus, the MYH9 and APOL1 gene variants that are more common in individuals of African descent should not have affected the results to any major degree [1].

Our study also has a number of strengths. The large cohort included practically all patients aged 20–69 years with ESRD diagnoses in the Swedish Hospital Discharge Register and Outpatient Register during the study period, which increases the generalisability of our results. Another strength is the use of personal identification numbers, which made it possible to follow individuals in different registers [41]. Data in the Swedish Hospital Discharge Register are almost complete. In 2001, identification numbers were 99.6% complete and the main diagnosis was missing for only 0.9% of hospitalisations [42]. A further strength is the high validity of the Hospital Discharge Register [21,22, 43]. About

85–95% of most diagnoses have been shown to be correct [21,22,43]. A limitation is that there has been no specific validation study for ESRD. However, validity for surgery procedure codes is generally high [21]. This is exemplified by the fact that for kidney transplantation there is 95% agreement between the Swedish Hospital Discharge Register and the Swedish Renal Registry [44]. The Swedish Renal Registry is a voluntary quality registry for patients with chronic renal failure in Sweden, and is maintained by the Swedish Renal Medical Association and the Swedish Transplantation Society. However, for the diagnosis of ESRD in patients without dialysis or transplantation the agreement is lower. For the diagnosis codes N18.4 (stage 4 CKD) and N18.5 (stage 5 CKD), agreement with the Swedish Renal Registry is only 36%, with coverage of 61% [45]. This is probably due to the use of N18.9 (unspecified renal failure) instead of N18.4 and N18.5 [45]. However, with regard to neighbourhood deprivation, this possible underreporting of N18.4 and N18.5 in the Swedish Hospital Discharge Register is most likely a source of non-differential bias. Moreover, in the present study only the N18.5 code (stage 5 CKD) was used; N18.4 (stage 4 CKD) was not used. The code N18.5 accounted for only 7.7% of patients (Supplementary Table 1). Thus, the present study mainly reflects patients with stage 5 CKD, who are treated with dialysis or renal transplantation.

5.3. Implications

The clustering of ESRD in deprived neighbourhoods raises clinical and public health concerns. The present findings suggest a need for a stronger focus on primary and secondary prevention of ESRD in deprived neighbourhoods.

6. Conclusion

Neighbourhood deprivation is associated with ESRD, independently of individual-level sociodemographic factors and comorbidities. These findings raise important clinical and public health concerns and indicate that both individual- and neighbourhood-level SES are important to consider in health care policies for patients with ESRD.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Jha V, Garcia-Garcia G, Iseki K, Li Z, Naicker S, Plattner B, et al. Chronic kidney disease: global dimension and perspectives. *Lancet*. 2013; 382:260–72. [PubMed: 23727169]

2. Levey AS, Coresh J, Balk E, Kausz AT, Levin A, Steffes MW, et al. Foundation NK: National Kidney Foundation practice guidelines for chronic kidney disease: evaluation, classification, and stratification. *Ann Intern Med.* 2003; 139:137–47. [PubMed: 12859163]
3. Levey AS, Atkins R, Coresh J, Cohen EP, Collins AJ, Eckardt KU, et al. Chronic kidney disease as a global public health problem: approaches and initiatives — a position statement from kidney disease improving global outcomes. *Kidney Int.* 2007; 72:247–59. [PubMed: 17568785]
4. Rostand SG, Brown G, Kirk KA, Rutsky EA, Dustan HP. Renal insufficiency in treated essential hypertension. *N Engl J Med.* 1989; 320:684–8. [PubMed: 2922014]
5. Perneger TV, Whelton PK, Klag MJ. Race and end-stage renal disease. Socioeconomic status and access to health care as mediating factors. *Arch Intern Med.* 1995; 155:1201–8. [PubMed: 7763126]
6. Krop JS, Coresh J, Chambless LE, Shahar E, Watson RL, Szklo M, et al. A community-based study of explanatory factors for the excess risk for early renal function decline in blacks vs whites with diabetes: the Atherosclerosis Risk in Communities study. *Arch Intern Med.* 1999; 159:1777–83. [PubMed: 10448782]
7. Foré CM, Ejerblad E, Fryzek JP, Lambe M, Lindblad P, Nyrén O, et al. Socio-economic status and chronic renal failure: a population-based case-control study in Sweden. *Nephrol Dial Transplant.* 2003; 18:82–8. [PubMed: 12480964]
8. Crews DC, Charles RF, Evans MK, Zonderman AB, Powe NR. Poverty, race, and CKD in a racially and socioeconomically diverse urban population. *Am J Kidney Dis.* 2010; 55:992–1000. [PubMed: 20207457]
9. Whittle JC, Whelton PK, Seidler AJ, Klag MJ. Does racial variation in risk factors explain black-white differences in the incidence of hypertensive end-stage renal disease? *Arch Intern Med.* 1991; 151:1359–64. [PubMed: 2064486]
10. Brancati FL, Whittle JC, Whelton PK, Seidler AJ, Klag MJ. The excess incidence of diabetic end-stage renal disease among blacks. A population-based study of potential explanatory factors. *JAMA.* 1992; 268:3079–84. [PubMed: 1433738]
11. Young EW, Mauger EA, Jiang KH, Port FK, Wolfe RA. Socioeconomic status and end-stage renal disease in the United States. *Kidney Int.* 1994; 45:907–11. [PubMed: 8196296]
12. Byrne C, Nedelman J, Luke RG. Race, socioeconomic status, and the development of end-stage renal disease. *Am J Kidney Dis.* 1994; 23:16–22. [PubMed: 8285192]
13. Merkin SS, Coresh J, Diez Roux AV, Taylor HA, Powe NR. Area socioeconomic status and progressive CKD: the Atherosclerosis Risk in Communities (ARIC) Study. *Am J Kidney Dis.* 2005; 46:203–13. [PubMed: 16112038]
14. Ward MM. Socioeconomic status and the incidence of ESRD. *Am J Kidney Dis.* 2008; 51:563–72. [PubMed: 18371532]
15. Bello AK, Peters J, Rigby J, Rahman AA, El Nahas M. Socioeconomic status and chronic kidney disease at presentation to a renal service in the United Kingdom. *Clin J Am Soc Nephrol.* 2008; 3:1316–23. [PubMed: 18579673]
16. Volkova N, McClellan W, Klein M, Flanders D, Kleinbaum D, Soucie JM, et al. Neighborhood poverty and racial differences in ESRD incidence. *J Am Soc Nephrol.* 2008; 19:356–64. [PubMed: 18057219]
17. McClellan WM, Newsome BB, McClure LA, Howard G, Volkova N, Audhya P, et al. Poverty and racial disparities in kidney disease: the REGARDS study. *Am J Nephrol.* 2010; 32:38–46. [PubMed: 20516678]
18. Merkin SS, Diez Roux AV, Coresh J, Fried LF, Jackson SA, Powe NR. Individual and neighborhood socioeconomic status and progressive chronic kidney disease in an elderly population: the Cardiovascular Health Study. *Soc Sci Med.* 2007; 65:809–21. [PubMed: 17499411]
19. Shoham DA, Vupputuri S, Kaufman JS, Kshirsagar AV, Diez Roux AV, Coresh J, et al. Kidney disease and the cumulative burden of life course socioeconomic conditions: the Atherosclerosis Risk in Communities (ARIC) study. *Soc Sci Med.* 2008; 67:1311–20. [PubMed: 18667261]
20. Ekblom A. The Swedish multi-generation register. *Methods Mol Biol.* 2011; 675:215–20. [PubMed: 20949391]

21. Ludvigsson JF, Andersson E, Ekbom A, Feychting M, Kim JL, Reuterwall C, et al. External review and validation of the Swedish national inpatient register. *BMC Public Health*. 2011; 11:450. [PubMed: 21658213]
22. Zöller B. Nationwide family studies of cardiovascular diseases — clinical and genetic implications of family history. *EMJ Cardiol*. 2013; 1:102–13.
23. Zöller B, Li X, Sundquist J, Sundquist K. Neighborhood deprivation and hospitalization for venous thromboembolism in Sweden. *J Thromb Thrombolysis*. 2012; 34:374–82. [PubMed: 22538704]
24. Zöller B, Li X, Sundquist J, Sundquist K. Neighbourhood deprivation and hospitalization for atrial fibrillation in Sweden. *Europace*. 2013; 15:1119–27. [PubMed: 23447572]
25. Li X, Sjöstedt C, Sundquist K, Zöller B, Sundquist J. Neighborhood deprivation and childhood autism: a nationwide study from Sweden. *J Psychiatr Res*. 2014; 53:187–92. [PubMed: 24613033]
26. Cubbin C, Sundquist K, Ahlén H, Johansson SE, Winkleby MA, Sundquist J. Neighborhood deprivation and cardiovascular disease risk factors: protective and harmful effects. *Scand J Public Health*. 2006; 34:228–37. [PubMed: 16754580]
27. Sundquist J, Johansson SE, Yang M, Sundquist K. Low linking social capital as a predictor of coronary heart disease in Sweden: a cohort study of 2. 8 million people. *Soc Sci Med*. 2006; 62:954–63. [PubMed: 16081195]
28. Winkleby M, Sundquist K, Cubbin C. Inequities in CHD incidence and case fatality by neighborhood deprivation. *Am J Prev Med*. 2007; 32:97–106. [PubMed: 17234484]
29. Callas PW, Pastides H, Hosmer DW. Empirical comparisons of proportional hazards, poisson, and logistic regression modeling of occupational cohort data. *Am J Ind Med*. 1998; 33:33–47. [PubMed: 9408527]
30. Goldstein, H. Multilevel statistical models. 3. London: Hodder Arnold Publishers; 2003.
31. Barbour SJ, Schachter M, Er L, Djurdjev O, Levin A. A systematic review of ethnic differences in the rate of renal progression in CKD patients. *Nephrol Dial Transplant*. 2010; 25:2422–30. [PubMed: 20519230]
32. USRDS annual data report: atlas of chronic kidney disease and end-stage renal disease in the United States. *Am J Kidney Dis*. 2013; 63(1):e1–478. Supplement.
33. Black PH, Garbutt LD. Stress, inflammation and cardiovascular disease. *J Psychosom Res*. 2002; 52:1–23. [PubMed: 11801260]
34. Holden L, Scuffham P, Hilton M, Vecchio N, Whiteford H. Psychological distress is associated with a range of high-priority health conditions affecting working Australians. *Aust N Z J Public Health*. 2010; 34:304–10. [PubMed: 20618274]
35. Sundquist K, Theobald H, Yang M, Li X, Johansson SE, Sundquist J. Neighborhood violent crime and unemployment increase the risk of coronary heart disease: a multilevel study in an urban setting. *Soc Sci Med*. 2006; 62:2061–71. [PubMed: 16203075]
36. Ejerblad E, Forel CM, Lindblad P, Fryzek J, Dickman PW, Elinder CG, et al. Association between smoking and chronic renal failure in a nationwide population-based case–control study. *J Am Soc Nephrol*. 2004; 15:2178–85. [PubMed: 15284303]
37. Sundquist J, Malmström M, Johansson SE. Cardiovascular risk factors and the neighbourhood environment: a multilevel analysis. *Int J Epidemiol*. 1999; 28:841–5. [PubMed: 10597980]
38. Van, Doorslaer; Wagstaff, A.; Bleichrodt, H.; Calonge, S.; Gerdtham, UG.; Gerfin, M., et al. Income-related inequalities in health: some international comparisons. *J Health Econ*. 1997; 16:93–112. [PubMed: 10167346]
39. Hardy D, Chan W, Liu CC, Cormier JN, Xia R, Bruera E, et al. Racial disparities in the use of hospice services according to geographic residence and socioeconomic status in an elderly cohort with nonsmall cell lung cancer. *Cancer*. 2011; 117:1506–15. [PubMed: 21425152]
40. Taylor DH Jr, Leese B. General practitioner turnover and migration in England 1990–94. *Br J Gen Pract*. 1998; 48:1070–2. [PubMed: 9624750]
41. Ludvigsson JF, Otterblad-Olausson P, Pettersson BU, Ekbom A. The Swedish personal identity number: possibilities and pitfalls in healthcare and medical research. *Eur J Epidemiol*. 2009; 24:659–67. [PubMed: 19504049]
42. Rosen, M.; Hakulinen, T. Handbook of epidemiology. Berlin: Springer-Verlag; 2005. Use of disease registers; p. 231–51.

43. Socialstyrelsen. Patientregistret 1987–1996 kvalitet och innehåll. Stockholm: Epidemiologiskt Centrum, Socialstyrelsen; 1998.
44. Socialstyrelsen. Rapporteringen till nationella kvalitetsregister och hälsodataregistren — jämförelser av täckningsgrader. Stockholm: Socialstyrelsen; 2012.
45. Socialstyrelsen. Rapporteringen till nationella kvalitetsregister och hälsodataregistren — jämförelser av täckningsgrader. Stockholm: Socialstyrelsen; 2013.

Table 1
Population characteristics and end stage renal disease (ESRD) by level of neighborhood deprivation: 2001–2010.

	Study population		ESRD events		Incidence of ESRD by level of neighborhood deprivation		
	(N)	(%)	(N)	(%)	Low	Moderate	High
Total population	5,593,516		12,348		1,301,351 (23.3%)	3,370,070 (60.2%)	922,095 (16.5%)
ESRD					1.8	2.3	2.5
Age (years)							
20–29	1,092,948	19.5	712	5.8	0.5	0.7	0.7
30–39	1,264,439	22.6	1520	12.3	0.9	1.3	1.5
40–49	1,163,403	20.8	2385	19.3	1.6	2.1	2.6
50–59	1,241,349	22.2	3950	32.0	2.6	3.2	4.0
60–69	831,377	14.9	3781	30.6	3.7	4.6	5.4
Gender							
Male	2,826,359	50.5	7870	63.7	2.3	2.9	3.1
Female	2,767,157	49.5	4478	36.3	1.3	1.6	1.9
Education level							
9 years	1,249,236	22.3	4336	35.1	2.3	2.9	3.0
10–12 years	2,700,091	48.3	5560	45.0	1.9	2.3	2.4
>12 years	1,644,189	29.4	2452	19.9	1.5	1.7	1.7
Marital status							
Married/cohabiting	2,575,915	46.1	6331	51.3	1.7	2.1	2.4
Never married, widowed, or divorced	3,017,601	53.9	6017	48.7	1.9	2.5	2.6
Family income							
Low income	1,399,791	25.0	2781	22.5	2.0	2.5	2.8
Middle–low income	1,400,677	25.0	3489	28.3	2.2	2.6	2.8
Middle–high income	1,396,660	25.0	3348	27.1	2.0	2.3	2.5
High income	1,396,388	25.0	2730	22.1	1.5	1.9	1.8
Country of origin							
Sweden	4,797,837	85.8	10,531	85.3	1.8	2.3	2.5
Finland	163,533	2.9	379	3.1	1.5	1.9	1.8
Western countries	51,828	0.9	119	1.0	1.6	1.8	2.6

	Study population		ESRD events		Incidence of ESRD by level of neighborhood deprivation		
	(N)	(%)	(N)	(%)	Low	Moderate	High
Eastern European countries	114,770	2.1	317	2.6	2.7	3.0	2.8
Middle Eastern countries	141,019	2.5	291	2.4	3.4	2.9	3.3
Others	324,529	5.8	711	5.8	1.9	2.4	2.8
Urban/rural status							
Large cities	2,854,538	51.0	6436	52.1	1.8	2.4	2.8
Middle-sized towns	1,852,901	33.1	3974	32.2	1.7	2.2	2.2
Small towns/rural areas	886,077	15.8	1938	15.7	1.7	2.1	2.3
Mobility							
Not moved	3,455,429	61.8	8912	72.2	1.8	2.3	2.5
Moved	2,138,087	38.2	3436	27.8	1.9	2.3	2.5
Chronic lower respiratory disease							
No	5,458,926	97.6	11,659	94.4	1.7	2.2	2.4
Yes	134,590	2.4	689	5.6	3.7	4.2	4.8
Alcoholism and related liver disease							
No	5,475,640	97.9	11,950	96.8	1.8	2.3	2.5
Yes	117,876	2.1	398	3.2	2.5	3.5	3.0
Obesity							
No	5,543,143	99.1	12,158	98.5	1.8	2.3	2.5
Yes	50,373	0.9	190	1.5	3.6	4.5	3.7
Coronary heart disease							
No	5,358,377	95.8	9307	75.4	1.5	1.8	2.0
Yes	235,139	4.2	3041	24.6	13.9	17.3	14.6
Diabetes							
No	5,426,241	97.0	8343	67.6	1.3	1.6	1.7
Yes	167,275	3.0	4005	32.4	19.2	23.4	22.9
Hypertension							
No	5,431,660	97.1	9502	77.0	1.5	1.8	2.0
Yes	161,856	2.9	2846	23.0	15.5	22.1	29.0
Acute kidney failure							
No	5,586,700	99.9	11,850	96.0	1.7	2.2	2.4

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	<u>Study population</u>		<u>ESRD events</u>		<u>Incidence of ESRD by level of neighborhood deprivation</u>		
	(N)	(%)	(N)	(%)	Low	Moderate	High
Yes	6816	0.1	498	4.0	90.6	88.4	88.3

Table 2

Odds ratios (ORs) and 95% confidence intervals (CI) for end stage renal disease (ESRD) in men; Results from multi-level logistic regression models.

	Model 1			Model 2			Model 3			Model 4			P-value
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		
Neighborhood deprivation (ref. low)													
Moderate	1.27	1.20	1.35	1.28	1.20	1.36	1.19	1.12	1.26	1.16	1.09	1.24	<0.001
High	1.32	1.22	1.43	1.45	1.34	1.56	1.25	1.15	1.35	1.17	1.07	1.27	<0.001
Age (years)				1.05	1.05	1.05	1.05	1.05	1.06	1.02	1.02	1.03	<0.001
Education level (ref. > 12 years)													
9 years							1.29	1.20	1.38	1.15	1.08	1.23	<0.001
10–12 years							1.20	1.13	1.28	1.10	1.03	1.17	0.003
Marital status (ref. married/cohabiting)													
Never married, widowed, or divorced							1.24	1.18	1.30	1.16	1.11	1.22	<0.001
Family income (ref. high income)													
Low income							1.29	1.20	1.39	1.25	1.17	1.34	<0.001
Middle–low income							1.39	1.31	1.49	1.31	1.23	1.40	<0.001
Middle–high income							1.30	1.22	1.38	1.23	1.16	1.31	<0.001
Country of origin (ref. Sweden)													
Finland							0.82	0.72	0.94	0.74	0.65	0.85	<0.001
Western countries							0.84	0.67	1.05	0.84	0.67	1.05	0.134
Eastern European countries							1.14	0.98	1.32	1.04	0.89	1.20	0.617
Middle Eastern countries							1.09	0.94	1.27	0.95	0.82	1.11	0.549
Others							1.02	0.92	1.12	0.97	0.88	1.08	0.576
Urban/rural status (ref. large cities)													
Middle-sized towns							0.84	0.79	0.88	0.90	0.85	0.95	<0.001
Small towns/rural areas							0.84	0.79	0.90	0.83	0.77	0.89	<0.001
Mobility (ref. not moved)							0.99	0.94	1.05	0.94	0.89	0.99	0.024
Chronic lower respiratory disease (ref. no)										1.28	1.15	1.43	<0.001
Alcoholism and related liver disease (ref. no)										0.92	0.82	1.03	0.162
Coronary heart disease (ref. no)										2.31	2.18	2.44	<0.001
Hypertension (ref. no)										4.83	4.56	5.11	<0.001

	Model 1			Model 2			Model 3			Model 4			P-value
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	
Diabetes (ref. no)									7.32	6.95	7.70		<0.001
Obesity (ref. no)									0.80	0.65	0.99		0.046
Acute kidney failure (ref. no)									9.35	8.26	10.57		<0.001
Variance (S.E.)	0.067 (0.014)		0.053 (0.014)				0.041 (0.014)				0.068 (0.014)		

Model 1 (the neighbourhood model) includes neighbourhood-level deprivation. Model 2 includes neighbourhood-level deprivation and age (as a continuous variable). Model 3 includes neighbourhood-level deprivation and the following sociodemographic variables as covariates: age (as a continuous variable), marital status, family income, education level, country of origin, urban/rural status, and mobility. Model 4 (the full model): model 3 + comorbidities.

Table 3

Odds ratios (ORs) and 95% confidence intervals (CI) for end stage renal disease (ESRD) in women; Results from multi-level logistic regression models.

	Model 1			Model 2			Model 3			Model 4			P-value
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		
Neighborhood deprivation (ref. low)													
Moderate	1.27	1.17	1.37	1.25	1.15	1.35	1.13	1.05	1.23	1.10	1.01	1.20	0.021
High	1.51	1.37	1.67	1.59	1.44	1.75	1.30	1.17	1.44	1.18	1.06	1.31	0.001
Age (years)				1.04	1.04	1.04	1.04	1.04	1.04	1.02	1.01	1.02	<0.001
Education level (ref. > 12 years)													
9 years							1.63	1.49	1.78	1.39	1.27	1.52	<0.001
10–12 years							1.35	1.24	1.46	1.25	1.15	1.35	<0.001
Marital status (ref. married/cohabiting)													
Never married, widowed, or divorced							1.15	1.08	1.22	1.08	1.01	1.15	0.016
Family income (ref. high income)													
Low income							1.24	1.12	1.36	1.07	0.97	1.18	0.194
Middle–low income							1.39	1.27	1.52	1.17	1.06	1.28	<0.001
Middle–high income							1.20	1.09	1.31	1.10	1.00	1.20	0.046
Country of origin (ref. Sweden)													
Finland							0.76	0.65	0.89	0.66	0.56	0.78	<0.001
Western countries							0.93	0.68	1.26	0.96	0.71	1.31	0.842
Eastern European countries							1.23	1.02	1.47	1.04	0.86	1.26	0.689
Middle Eastern countries							1.06	0.86	1.31	0.88	0.71	1.08	0.230
Others							1.07	0.94	1.21	1.05	0.93	1.19	0.424
Urban/rural status (ref. large cities)													
Middle-sized towns							0.90	0.84	0.97	0.96	0.90	1.03	0.317
Small towns/rural areas							0.87	0.79	0.95	0.86	0.78	0.94	<0.001
Mobility (ref. not moved)							0.96	0.90	1.03	0.91	0.85	0.98	0.009
Chronic lower respiratory disease (ref. no)										1.41	1.25	1.60	<0.001
Alcoholism and related liver disease (ref. no)										1.31	1.06	1.62	0.012
Coronary heart disease (ref. no)										2.66	2.44	2.89	<0.001
Hypertension (ref. no)										4.44	4.11	4.80	<0.001

	Model 1			Model 2			Model 3			Model 4			P-value
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		
Diabetes (ref. no)										8.78	8.16	9.44	<0.001
Obesity (ref. no)										0.91	0.74	1.12	0.368
Acute kidney failure (ref. no)										7.98	6.59	9.67	<0.001
Variance (S.E.)	0.070 (0.023)			0.059 (0.023)			0.047 (0.022)			0.073 (0.023)			

Model 1 (the neighbourhood model) includes neighbourhood-level deprivation. Model 2 includes neighbourhood-level deprivation and age (as a continuous variable). Model 3 includes neighbourhood-level deprivation and the following sociodemographic variables as covariates: age (as a continuous variable), marital status, family income, education level, country of origin, urban/rural status, and mobility. Model 4 (the full model): model 3 + comorbidities.