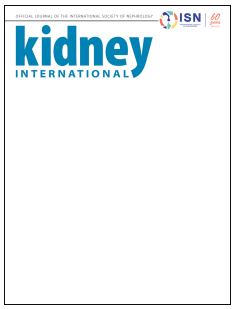

Individual and neighborhood-level social and deprivation factors impact kidney health in the GLOMMS-CORE study

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PII: S0085-2538(24)00545-3

DOI: https://doi.org/10.1016/j.kint.2024.07.021

Reference: KINT 3927

To appear in: *Kidney International*

Received Date: 18 March 2024

Revised Date: 14 June 2024

Accepted Date: 11 July 2024

Please cite this article as: Sawhney S, Atherton I, Blakeman T, Black C, Cowan E, Croucher C, Fraser SD, Hughes A, Nath M, Nitsch D, Scholes-Robertson N, Diaz MR, Individual and neighborhood-level social and deprivation factors impact kidney health in the GLOMMS-CORE study, *Kidney International* (2024), doi: https://doi.org/10.1016/j.kint.2024.07.021.

[QUERY TO AUTHOR: title and abstract rewritten by Editorial Office – not subject to change]

Individual and neighborhood-level social and deprivation factors impact kidney health in the GLOMMS-CORE study.

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Funding

This research, as part of the KINDER (Kidney Inequalities: Needs, Data, Experiences, Response) study, was supported by project grants from NHS Grampian Charities (20/001), and from the Scottish Government's Chief Scientist Office (HIPS/23/17).

Acknowledgements

We acknowledge the support of the Grampian Data Safe Haven (DaSH) facility within the Aberdeen Centre for Health Data Science and the associated financial support of the University of Aberdeen, and NHS Research Scotland (through NHS Grampian investment in DaSH). For more information, visit the DaSH website: http://www.abdn.ac.uk/iahs/facilities/grampian-data-safe-haven.php. The authors would like to acknowledge the support of the eDRIS Team (Public Health Scotland), in particular Fiona James, for their involvement in obtaining approvals, provisioning and linking data and for the use of the secure analytical platform within the National Safe Haven. This work contains statistical data from the National Records of Scotland (NRS) which is Crown Copyright. The use of NRS statistical data in this work does not imply the endorsement of NRS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates. We are also grateful to Mrs Neerja Jain (Kidney Research UK) and Professor Paul Cockwell (UK Kidney Association) for feedback on the design of the KINDER study.

Abstract

Prospective cohort studies of kidney equity are limited by a focus on advanced rather than early disease and selective recruitment. Whole population studies frequently rely on area-level measures of deprivation as opposed to individual measures of social disadvantage. Here, we linked kidney health and individual census records in the North of Scotland (Grampian area), 2011-2021 (GLOMMS-CORE) and identified incident kidney presentations at thresholds of estimated glomerular filtration rate (eGFR) under 60 (mild/early), under 45 (moderate), under 30 ml/min/1.73m^2(advanced), and acute kidney disease (AKD). Household and neighborhood socioeconomic measures, living circumstances, and long-term mortality were compared. Case-mix adjusted multivariable logistic regression (living circumstances), and Cox models (mortality) incorporating an interaction between the household and the neighborhood were used. Among census respondents, there were 48546, 29081, 16116, 28097 incident presentations of each respective eGFR cohort and AKD. Classifications of socioeconomic position by household and neighborhood were related but complex, and frequently did not match. Compared to households of professionals, people with early kidney disease in unskilled or unemployed households had increased mortality (adjusted hazard ratios: 95% confidence intervals) of (1.26: 1.19-1.32) and (1.77: 1.60-1.96), respectively with adjustment for neighborhood indices making little difference. Those within either a deprived household or deprived neighborhood experienced greater mortality, but those within both had the poorest outcomes. Unskilled and unemployed households frequently reported being limited by illness, adverse mental health, living alone, basic accommodation, lack of car ownership, language difficulties, visual and hearing impairments. Thus, impacts of deprivation on kidney health are spread throughout society, complex, serious, and not confined to those living in deprived neighborhoods.

Keywords

Chronic Kidney Disease; Equity; Epidemiology; Health inequalities; Social determinants

Lay Summary

Existing research looking into equity of kidney health and care frequently suffers from insufficient detail by describing the neighbourhoods that people live in rather than people themselves, or from insufficient representativeness by not covering everyone in a population. This makes it hard to ensure that future kidney health policies can help everyone fairly.

We addressed these shortcomings by linking the kidney health and care data for all people living in the North of Scotland (Grampian), to their census records. We found evidence of the harms of deprivation on kidney health spread throughout society, and not confined solely to those living in deprived areas. Furthermore, even in the early stages of kidney disease people from deprived backgrounds report more difficulties related to ill health, mental health, living alone, basic accommodation, no car, language, and communication. Collectively, these challenges may affect their opportunities to have good kidney health and to live well.

Introduction

People in deprived communities develop kidney disease earlier, experience less proactive care, progress more rapidly towards kidney failure, and die younger. [1, 2] While literature on the equity of access to kidney care has focused on the most advanced stages of kidney disease, there is increasing recognition of the importance of early kidney care. [2-5] Calls to improve early detection and care [6-9] have prompted innovative interventions including peer support, navigation, and education campaigns [10-16]; screening and targeted case finding [3, 7, 17-19]; improvements in information technology and coordination of care [20-22]; and remote care / telehealth. [23, 24] For these complex interventions to have an equitable implementation, they must be selected and aligned to reach and meet the needs of different communities that are under-served. Where mis-aligned, well-intended interventions risk broadening rather than narrowing inequities by failing to reach their intended groups, or by unintentionally de-prioritising others. [25-27] Thus, a lens of equity requires an explicit break from a "one size fits all" assumption, informed first by detailed evidence of who is underserved, how and why [28]; before designing, selecting, and adapting interventions. [29]

Existing evidence of kidney health equity lacks this detail, suffering from deficient population coverage and suboptimal data quality. Evidence draws from selective cohorts of people who are more visible and are already accessing kidney care [4, 30-34]; or from broader general population cohorts that are less selective but have limited detail. [35] Studies that look at individual measures of deprivation and kidney health also tend to be of cross-sectional nature, which means that outcomes cannot be reliably estimated. Consequently, existing knowledge is insufficient for understanding the living circumstances and challenges faced by potentially under-served people. [2, 36-39] For instance, population area-level studies of neighbourhood deprivation may be sufficient to restate the inequity that we already know, but lack the finer detail for understanding intersecting relationships and mechanisms. While not evaluated in kidney research, recent cancer literature suggests that area-level deprivation may capture only part of the relationship between deprivation and health outcomes. Individual-level socioeconomic factors describe more complex patterns of cancer care and outcomes above what can be captured at an area-level. [40, 41] Moreover, high quality care may be promoted or undermined by multiple intersecting factors including occupation, sex, gender, ethnicity, religion, race, rurality, transport, education, health and digital literacy, language, disabilities, mental health, dependency, housing circumstances, and social isolation. [1] For this reason, the use of area deprivation measures as a "catch all" has drawn criticism when cascaded into policy, interventions and decision support tools. [42, 43] To move from simply appreciating that inequities exist in early kidney care to understanding how and why they occur, new sources of relevant and accurate data are required.

To our best knowledge, this analysis is the first study linking the kidney health of a whole population (in the North of Scotland) to Census records. All Scottish adult residents are required to complete the census every ten years, covering information on individuals, their household composition, employment, education, qualifications, ethnicity, language, wellbeing and living circumstances. Our aims were twofold: (1) to assess in a general population of people presenting with kidney disease, whether household socioeconomic status is associated with subsequent mortality independent of neighbourhood measures of deprivation; and (2) to understand how the living circumstances of people presenting with kidney disease vary according to household socioeconomic status, neighbourhood, and kidney disease severity.

Methods

Linkage of GLOMMS population health data and Scottish census data (GLOMMS-CORE)

The "Grampian Laboratory Outcomes Morbidity and Mortality Study" (GLOMMS) features twenty years of routine kidney health data from all resident people with kidney disease living in the Grampian region of the North of Scotland. [2, 44, 45] Scotland is a high-income country with universal healthcare, but has the highest mortality in Western Europe, and a widening health gap between the most and least deprived areas. [46] While Grampian compares favourably with other regions of Scotland, areas of both affluence and deprivation are dispersed, and Grampian contains both some of the most deprived and affluent neighbourhoods of Scotland.

For this analysis, a "Core determinants and Equity" linkage to GLOMMS (GLOMMS-CORE) combined the health records of all people in GLOMMS with their responses to the Scottish Census in 2011. A compulsory Scotland-wide census of residents in 2011 was completed by 90% of people. [47] Linkages to GLOMMS were performed using the community health index (CHI) – a unique identifier for every Scottish resident. This work was conducted with approvals from NHS Grampian Caldicott, North West Research Ethics Committee (19/NW/0552), NHS Research and Development, and the Statistics Public Benefit and Privacy Panel of the Scottish Government (1920-0075).

Derivation of study populations

This study involved the linkages of four parallel kidney cohorts of people living in Grampian with incident kidney presentations based on their population laboratory results 2011-2021. This is summarised in **Figure 1**, and in our previous work. [2] In each of the four cohorts, adults aged ≥18 years were included from the date when they had a laboratory test of kidney disease that crossed a severity threshold based on a Chronic Kidney Disease Epidemiology Consortium (CKD EPI 2009 without correction for race) estimated glomerular filtration rate (eGFR) of below 60, 45, 30 ml/min/1.73 m^2 (i.e. mild/early, moderate and advanced disease respectively), and the first (incident) instance of acute kidney disease (AKD) using a Kidney Disease: Improving Global Outcomes (KDIGO) aligned algorithm. All kidney-related definitions have been implemented and replicated in previous work, with code and coding dictionaries available. [48, 49] As described elsewhere, using two eGFR results to meet the chronicity criterion can introduce bias because people who receive more frequent tests must survive to the next test, and may either be "sicker" or have advantaged access to blood tests. [50] In this study, the outcome is mortality, and people who may have disadvantaged access are of particular interest. Therefore, to avoid bias we used anyone with a single result of reduced kidney function. Our AKD definition was updated for this study based on recent work recommending that AKD algorithms should be constrained to within a 90-day window. [49] Our focus for study was *incident* (new presentations) rather than prevalent patients, and therefore we applied a two-year exclusion period (2009-2010) to avoid a 'prevalent pool effect' (i.e. inadvertent mixing of prevalent and incident patients). People in each of these four parallel kidney cohorts were then linked to their census records to form the study populations.

Exposures and Comparators: Household and neighbourhood socioeconomic measures

For the household socioeconomic measure, we used the National Statistics Socio-economic Classification (NS-SEC) [51] of the "household reference person" as recorded in the census. Household NS-SEC is an occupation-based social measure. In contrast to NS-SEC of an "*individual*" person, "*household*" NS-SEC recognises that an individual's circumstances may be less relevant to their socioeconomic position than another member of the same household (e.g. a spouse). The household reference person is the person responsible for owning or renting the accommodation, and if there are joint householders, the person with the highest income takes precedence. [51] Household NS-SEC classification is conventionally collapsed into categories of people of similar socioeconomic

position. In Box 1, we have listed these categories with example occupations. [51-54] Categories 6-8 are sometimes referred to as "working class." [52] In our analyses we compared with "unskilled" and "unemployed" categories with a reference "affluent" category of "managers and professionals".

For the neighbourhood socioeconomic measure, we used the Scottish Index of Multiple Deprivation (SIMD) from 2016, [55] as determined by resident postcode. This metric covers an aggregate of measures for a given local neighbourhood area across seven domains of income, employment, education, health, access to services, crime and housing. SIMD is traditionally reported within quintiles ranging from neighbourhoods within the most deprived 20% of Scotland (quintile 1), to the most affluent 20% of Scotland (quintile 5).

In sensitivity analyses we also used NS-SEC for the individual rather than household, and individual (five level, A to E) social grade category. Social grade is a less commonly used alternative measure developed originally from market research, and approximated from Census responses using a validated algorithm combining details of current occupation, occupation of the household reference person, last main job among those not working, age, qualifications, type of housing and tenure. [56]

Additional social variable from the GLOMMS-CORE census linkage

A dictionary of variables mapped to the 2011 Census is provided in the supplementary material. Detailed additional metadata and provenance are available at a dedicated Census website. [57] The variables of social and living circumstances derived from the census that received approval for linkage and were reported here include socioeconomic position and social grade of individual and household; self-reported ethnicity and place of birth; current work; qualifications; activity limitation due to ill health; self-rated level of general health; mental health; physical disabilities; household occupants and isolation; household accommodation (known as "occupancy rating", a measure of whether there are sufficient available rooms for the number of household occupants); carers within the household; access to a car; English language fluency (ability to speak, read, and write); visual and hearing impairment.

Additional variables from GLOMMS health dataset

Available variables included age; sex; comorbidities; prescribed medications; monitoring and results of blood and urine tests; dates and outcomes of emergency department, outpatient and inpatient attendances. Comorbidities in the analyses were prior history of cancer, chronic obstructive pulmonary disease, coronary heart disease, diabetes, heart failure, hypertension, liver disease, peripheral arterial disease, stroke as far back as 2004, as described in previous work. [2] Using information from resident postcode, we also reported the Scottish Urban Rural Classification as a measure of rurality. [58]

Outcome – date of death

For survival analysis the outcome was the date of death from all causes, with follow up from incident presentation until either death or censoring at 1st January 2021 (i.e. up to ten years).

Statistical analyses

Across each of the four parallel cohorts of incident kidney presentations (at eGFR <60; <45; <30; AKD), we described cohort characteristics, SIMD (neighbourhood) quintiles, and household NS-SEC categories. We cross-tabulated household NS-SEC categories against SIMD quintiles to establish extent of overlap between household and neighbourhood deprivation measures. We described social and living characteristics of people in deprived and affluent household and neighbourhood categories. Finally, we reported the association household level deprivation with long term mortality independent of neighbourhood deprivation.

For each of the four cohorts, to understand how living circumstances varied by household ("unskilled" and "unemployed" households vs "professionals") and neighbourhood (most deprived vs most affluent quintile), we used multivariable logistic regression adjusting for age and sex to estimate odds ratios of each living circumstance (i.e. the odds of being "limited a lot" by health, of living alone, of having no access to a car etc).

In each cohort, to assess long-term mortality, we fitted Cox models to estimate mortality hazard ratios for "unskilled" and "unemployed" households vs "professionals" accounting for age and sex and neighbourhood SIMD quintile. Additionally, we determined that comorbidities could mediate (rather than confound) the association of socioeconomic position and mortality and therefore additionally adjusted for comorbidities at the time of presentation to assess if this explained any excess mortality. [2] In recognition of a potential circular relationship of a household being classified as "unemployed" as a consequence of rather than the cause of an individual's poor health, we excluded people who reported themselves to be on "long-term sick leave" in sensitivity analyses.

Finally, we focused on those with newly presenting early kidney disease (eGFR <60 ml/min/1.73m^2) to explore the joint relationships of household, neighbourhood area and health outcomes. We plotted a cross-tabulated heatmap of hazard ratios derived from age and sex adjusted Cox models incorporating an interaction between household NS-SEC and neighbourhood SIMD quintile. We tested for interaction significance using a likelihood ratio test of nested models. In supplementary analyses, we repeated this analysis for each kidney severity cohort, and subset by sex and year of entry. We plotted Kaplan Meier survival curves across all socioeconomic positions unadjusted, adjusted, and excluding long-term sick as described above. All analyses were performed using Stata/SE 17 (StataCorp), [59] with definitions and coding syntax for measures of kidney disease shared in previous work. [48, 49]

Results

Cohort Characteristics

Consistent with the Scottish Population, 90% of people with kidney disease completed a Census at incident severity thresholds of eGFR <60, <45, <30, and AKD, leading to 45846, 29081, 16116, and 28097 people in the main analyses (**Figure 1**). Broadly those who did not complete a census questionnaire were several years younger and had marginally fewer comorbidities (**Supplementary Table S1**).

We compared the characteristics of people in each of the four kidney cohorts with the underlying Grampian population (**Table 1**). The mean age was over 70 years compared to just below 50 for the general population, 99% White and 97% born in the UK, compared with 90% for the general population. People with kidney disease were distributed widely across all socioeconomic positions and social grades. When numbers of new kidney presentations were expressed as a proportion of people who completed the census, 10% of census respondents had a presentation of early kidney disease (eGFR <60), including 7.9% of professionals, 13.4% of people in unskilled households, and 13.5% of people in unemployed households (**Supplementary Table S2**).

Comparison of household vs neighbourhood socioeconomic position

In all kidney cohorts, compared to deprived neighbourhoods (SIMD quintile 1), a greater proportion of people living in affluent neighbourhoods (SIMD quintile 5) were from professional households and a lower proportion were from unskilled or unemployed households. Even so, there was a substantial lack of overlap between households and neighbourhood deprivation level, such that in all areas health providers who look after those with kidney disease would see people from all social backgrounds in their clinics (**Table 2** and **Supplementary Table S3**).

Individual social and living circumstances

People presenting with early kidney disease who were from unskilled or unemployed households had greater age and sex adjusted odds of reporting adverse living circumstances than those from professional households. This included loss of an individual's ability to remain in work, lack of educational qualifications, limitation due to loss of physical and mental wellbeing, living alone, living in basic accommodation, lack of a car, and difficulties with English language, vision or hearing (**Figure 2**). In addition, for each of these respective living circumstances, the odds of adverse living were similarly increased among those living in more deprived vs affluent neighbourhoods (**Figure 3**). **Figures 2 and 3** describe these patterns for those presenting with early kidney disease, and **Supplementary Tables S4 and S5** show that these patterns also existed for those presenting with more advanced or acute disease, with even more frequent reports of limitation due to health.

Long term mortality

Compared to people in professional households, people with new early kidney disease in unskilled or unemployed households had increased age-sex-neighbourhood adjusted hazards of mortality (respective hazard ratios, HR, and 95% confidence intervals, CI, of 1.26, 1.19-1.32 and 1.77, 1.60-1.96), with adjustment for neighbourhood indices making little difference (**Table 3**). In additional analyses, excess mortality changed little after adjusting for comorbidities, or when those "long-term off sick" were excluded. However, mortality hazard ratios were attenuated among people with more advanced or acute kidney disease. The pattern was the same when socioeconomic position was classified by an individual's social grade (**Supplementary Table S6**).

An expansion of the combined excess mortality hazards of both household and neighbourhood deprivation is provided as a cross-tabulated heatmap in **Figure 4** (and **Supplementary Figure S1** for social grade). An interaction term for household x neighbourhood was not significant (P = 0.54) consistent with separate independent associations of household and neighbourhood area with mortality. Thus, those in unskilled or unemployed households experienced greater mortality than professional households, and even greater mortality if they also lived in a deprived neighbourhood (SIMD 1). Similarly, while people in professional households had the lowest mortality overall, they were still more likely to die if they lived in a deprived neighbourhood. Moreover, the

pattern of attenuating excess mortality for disadvantaged neighbourhoods and households at later stages of kidney disease (described in **Table 3**) was also evident when cross-tabulated in heat maps across different kidney severity stages (**Supplementary Figure S2**).

As illustrated in **Figure 5**, this pattern of excess mortality was a gradient rather than a dichotomy, with both poorer survival for "unskilled" (pink) and "unemployed" (purple) households, and better survival for "professional" (blue) households vs those categorised in other household categories (grey). These findings were irrespective of household classification measure, statistical adjustment, or exclusion of those on long-term sick leave. Excess mortality was evident for both males and females (**Supplementary Figure S3**, and if the cohort was reduced to those presenting closest temporally (2011-2015) to the Census of 2011 (**Supplementary Figure S4**).

Discussion

In a large Scottish linked health and census study (GLOMMS-CORE), we report a complex picture in which both household and neighbourhood socioeconomic deprivation are associated with poorer health outcomes, physical, social, and mental wellbeing. People with early kidney disease who lived in *either* deprived households or deprived neighbourhoods experienced greater mortality, but those who experienced *both* household and neighbourhood deprivation were the most disadvantaged. Moreover, household and neighbourhood classifications often did not match, which has particular implications for policies or interventions that take account of one but not the other. Moreover, evidence for disadvantaged mortality outcomes was greatest for those presenting with early kidney disease, which supports calls for early detection and prompts initial preventive action while there is still opportunity to act and modify the clinical course.

Beyond measures of socioeconomic position or deprivation, GLOMMS-CORE also provides individual-level self-reported insight into the social circumstances of how people live and how they experience kidney disease. These included factors of wellbeing including physical, mental health and degree of limitation; factors that may affect navigation of healthcare or travel to appointments; ability to access, understand and act on information; and isolation or potential support within the household.[60] Notably, even at early stages of detected kidney disease up to 1 in 4 people in deprived areas were already limited by poor health, with 1 in 5 already on long-term sick leave from work. Many people reported living alone or with no access to a car for transport, across kidney severities, social positions, and neighbourhood areas. We also identified a substantial minority of people with English language difficulties, learning, visual and hearing impairments. These factors were related to household and neighbourhood socioeconomic position but did not fully align with either. Together these factors are consistent with a complex network of determinants [61] and accumulating disadvantages, [62] which we will incorporate in next steps to evaluate how kidney health and care are experienced (e.g. self-rated measures of wellbeing), are accessed (e.g. clinical location and timeliness of kidney disease detection), and align with evidenced-based recommendations (e.g. care processes of monitoring and prescribing).

This analysis contains several implications for health policy and planning. First, socioeconomic deprivation is not confined to discrete areas, but is spread throughout society, associated most inequitably with poor health outcomes early in the course of kidney disease, and not "explained" by clinical differences in morbidity burden at

presentation. Potential causes of disadvantaged access to care are numerous, are likely to intersect, and are not based solely on occupation or material wealth. Elsewhere we have shown that disadvantaged communities are more likely to have kidney disease first detected in a "reactive" emergency setting rather than through "proactive" community monitoring, with more missed appointments, and less blood test monitoring. [2] Thus, inequity in kidney disease outcomes may in part be mediated by deficiencies in early preventive care. To address these deficiencies, both in the UK and in other high-income countries, interventions to improve early kidney care (the point where the inequity is greatest) are likely to require careful tailoring and targeting to reach those in most need and not be based on area alone as has occurred previously. [42, 43] Such interventions may include interventions that currently exist (e.g. awareness campaigns, screening, patient navigation, electronic prompts for kidney monitoring, prescribing of beneficial new therapies such as SGLT2 inhibitors), but adapted through systematic planning and evaluation to ensure that we are better able to recognise and meet those in greatest need; supported with leadership, political will, and the necessary resources. [29] Second, many people with kidney disease experience challenges with respect to living circumstances, transport, and communication that generally lack a health data footprint. Closing this gap with relevant and reliable data may help us to become more proactive in designing and monitoring both the intended and unintended reach of new interventions. This is achievable but is likely to require both resource and closer working or partnerships with local authorities, voluntary organisations and peers within those communities. Third, we note that a high proportion of people presenting with early kidney disease in this analysis were already limited by their health, rated their health "bad" or "very bad", or were on long-term sick leave. This contrasts with patient facing information which often describes that "there are usually no symptoms of kidney disease in the early stages," [63] and may relate to the presence of other concurrent long-term conditions or delays in presentation. We suggest that healthcare professionals and patient facing literature should be mindful when discussing the implications of early kidney disease with people that it is usually not experienced in isolation but is integrated with other long-term conditions, well-being, psychosocial circumstances, and the everyday challenges that people face. [64] Similarly, clinicians should be prepared therefore to move beyond a focus on a single medical condition to acknowledge and support patients who are experiencing the effects of ill health on their social and everyday living circumstances even at early stages of kidney disease. [65, 66]

Our analysis adds to existing literature from recruited cohorts in the US reporting a relationship between household income and development of CKD in adults in the third National Health and Nutrition Examination Survey (NHANES III), [31, 33, 67] between socioeconomic status and development of CKD in the Atherosclerosis Risk in Communities (ARIC) study, [62] between neighbourhood area and progression of CKD in children in the Chronic Kidney Disease in Children cohort (CKID), [30] in addition to a relationship between education and CKD in the Prevention of Renal and Vascular End-stage Disease (PREVEND) in Europe. [34, 68] Our analysis adds to these recruited cohorts: by using a non-selective adult population, by combining both neighbourhood and household measures, and by showing greater evidence of inequity at early vs later stages of disease. Further analyses from the Study of Heart and Renal Protection (SHARP) trial reported increased risk of mortality and vascular events among people with CKD without formal education, [69] and increased risk of falling into poverty among people with advanced CKD. [32] While not directly addressed in this analysis these are relationships that we plan to replicate and explore further in our subsequent work. Our analysis also builds further to a chain of existing evidence for the need to intervene earlier in the clinical and life course [70]: covering relationships between antenatal kidney size and childhood health [71]; childhood risk factors and adult CKD [30, 72]; and adult education / general health awareness and subsequent poorer kidney health. [34, 73] Finally, our analysis also extends emerging cancer research on the limitations of area-based measures of deprivation by demonstrating similar limitations and complexity for people with kidney diseases. [40]

Strengths of this study include the full population linkage of health and social data at an individual level. All people who were detected newly with reduced eGFR and had a census record were included in this study even if they and their healthcare provider did not recognise the kidney impairment on their blood results. This addresses some selection issues and imprecise measures in other studies. Even so, we recognise that this still relies on a blood test happening, which means that some of the challenges faced by people may still be under-represented. Concerns of inequitable care based on race and ethnicity are substantial and sobering, particularly in studies from the U.S. [74] We could not study this as the population identified with kidney disease was composed 99% of White people, which reflects the limited diversity of elderly people living in Scotland. Even so, Grampian has strengths of being a well-studied region of Scotland with a similar case-mix adjusted burden of kidney disease and outcomes to high income countries elsewhere in Europe and North America, [48, 75] which also contain a mixture of both deprived and affluent areas and are likely to experience similar challenges with respect to inequitable detection, monitoring and access to early kidney care. [76, 77] We also reported each of the social and living circumstances separately, whereas many sources of disadvantage are likely to interact or intersect. This will be a natural next step of our work as part of the KINDER (Kidney Inequalities: needs data experiences and response) study. [78] We recognise that our study is based on the living circumstances people reported at a fixed time point of the census in 2011, whereas people presented with kidney disease at different time points from 2011 onwards. This means that we need to be cautious about the causal direction of socioeconomic circumstances impacting subsequent health, although this interpretation is plausible when taken in the context of wider knowledge and understanding. [79] This also means that our study covered a pre-pandemic era, but we know that health inequities in Scotland have widened over the last decade and therefore this analysis may underestimate the extent of current inequity. [46] We also recognise that comorbidity adjustment, while not central to the analysis, was based on hospitalisation episodes. This will have captured serious conditions, but will have missed stable conditions under review in primary care, such as hypertension. Finally, we acknowledge that this analysis comes from a universal healthcare system in a high-income country, whereas globally many people with kidney disease suffer from profound poverty, lack of personal safety, and poor health system infrastructure that precludes even basic preventive healthcare, monitoring, and support.

In conclusion, in a newly linked population health and social dataset of people with kidney disease (GLOMMS-CORE), we found evidence of the harms of deprivation spread throughout society, and not confined solely to those living in deprived areas. Patterns of neighbourhood deprivation and adverse household socioeconomic position were complex. Both separately were associated with poorer kidney health outcomes, while people who experienced both together were the most disadvantaged – especially early in the clinical course. Moreover, even in the early stages of kidney disease individuals reported deteriorating health and well-being, physical disabilities, adverse mental health, isolation, lack of access to transport, and difficulties relating to language and communication. These challenges may all affect their ability to attain good kidney health, healthcare and live well.

Disclosures

All of the authors declared no competing interests.

Data Sharing

Data access would require approval by Scotland's Public Benefit and Privacy Panel for Health, Scotland's Statistics Public Benefit and Privacy Panel, and appropriate ethical committees. Information on how researchers may make requests to obtain similar datasets from the health research dataset custodians may be provided upon request.

Acknowledgements

We acknowledge the support of the Grampian Data Safe Haven (DaSH) facility within the Aberdeen Centre for Health Data Science and the associated financial support of the University of Aberdeen, and NHS Research Scotland (through NHS Grampian investment in DaSH). For more information, visit the DaSH website: http://www.abdn.ac.uk/iahs/facilities/grampian-data-safe-haven.php. The authors would like to acknowledge the support of the eDRIS Team (Public Health Scotland), in particular Fiona James, for their involvement in obtaining approvals, provisioning and linking data and for the use of the secure analytical platform within the National Safe Haven. This work contains statistical data from the National Records of Scotland (NRS) which is Crown Copyright. The use of NRS statistical data in this work does not imply the endorsement of NRS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates. We are also grateful to Mrs Neerja Jain (Kidney Research UK) and Professor Paul Cockwell (UK Kidney Association) for feedback on the design of the KINDER study.

Funding

This research, as part of the KINDER (Kidney Inequalities: Needs, Data, Experiences, Response) study, was supported by project grants from NHS Grampian Charities (20/001), and from the Scottish Government's Chief Scientist Office (HIPS/23/17).

Supplementary Material

Table S1 – Characteristics of those with and without a completed census record

Table S2 – Percentage of census respondents presenting with early kidney disease according to household (NS-SEC) and neighbourhood (SIMD) socioeconomic position

Table S3 – Comparison of individual (Social Grade) and neighbourhood (SIMD) socioeconomic position across the four kidney disease cohorts

Table S4 – Living circumstances based on household socioeconomic position (NS-SEC) across all kidney disease cohorts

Table S5 – Living circumstances based on neighbourhood area deprivation quintile (SIMD) across all kidney disease cohorts

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Census measures data dictionary.xlsx

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Figure 1 – Linkage and development of study population

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Figure 3 – Living circumstances of people presenting with early kidney disease based on neighbourhood deprivation quintile (SIMD). Case-mix adjusted odds ratios depicted with black diamonds, with 95% confidence intervals for most deprived vs most affluent neighbourhood areas.

Figure 4 – Age and sex adjusted mortality hazard ratios for people presenting with early kidney disease eGFR <60 according to household (NS-SEC) and neighbourhood (SIMD) socioeconomic position

Figure 5 – Long-term mortality of people presenting with early kidney disease (eGFR <60) by household (NS-SEC) and individual (Social Grade) socioeconomic position

Category	NS-SEC definition	Occupation examples
1 & 2	Managers and professionals	Lawyers, architects, medical doctors, chief executives, economists, social workers, nurses, journalists, retail managers, teachers
3 & 4	Intermediate occupations and small employers	Paramedics, nursery nurses, farmers, shopkeepers, taxi drivers, driving instructors, window cleaners
5	Lower supervisory and technical occupations	Mechanics, chefs, train drivers, plumbers, electricians
6	Semi-routine ("semi-skilled" occupations)	Traffic wardens, receptionists, shelf-stackers, care workers, telephone salespersons
7	Routine ("unskilled" or casual work)	Bar staff, cleaners, labourers, lorry drivers
8	Never worked or long term unemployed	No regular employment

Box 1 – Categories of the Household National Statistics Socioeconomic Classification (NS-SEC) and example occupations.

	eGFR <60[2] (%)		eGFR <45 (%)		eGFR <30 (%)		AKD (%)		All adults	
N (with complete data)	45,846		29,081		16,116		28,097		458,897	
Age at presentation, mean (S.D.)	71.3	(14.2)	75.0	(12.8)	76.8	(12.9)	70.5	(16.6)	47.4	(18.5)
Female sex	25,205	(55.0)	15,981	(55.0)	8,683	(53.9)	14,706	(52.3)	234,301	(51.1)
"White" ethnic group	45,405	(99.0)	28,887	(99.3)	16,015	(99.4)	27,795	(98.9)	414,377	(90.3)
Born in the UK	44,298	(96.6)	28,242	(97.1)	15,682	(97.3)	27,064	(96.3)	411,463	(89.7)
SIMD area quintile of Scotland										
5 (most affluent)	13,673	(29.8)	8,268	(28.4)	4,383	(27.2)	7,845	(27.9)	154,457	(33.7)
4	13,346	(29.1)	8,332	(28.7)	4,606	(28.6)	7,934	(28.2)	130,562	(28.5)
3	9,794	(21.4)	6,387	(22.0)	3,544	(22.0)	6,130	(21.8)	91,824	(20.0)
2	7,134	(15.6)	4,841	(16.6)	2,802	(17.4)	4,810	(17.1)	63,023	(13.7)
1 (most deprived)	1,899	(4.1)	1,253	(4.3)	781	(4.8)	1,378	(4.9)	19,031	(4.1)
Rural home location[1]										
urban	25,298	(55.2)	16,469	(56.6)	9,210	(57.1)	16,247	(57.8)	245,752	(53.6)
accessible small town	4,181	(9.1)	2,583	(8.9)	1,458	(9.0)	2,468	(8.8)	49,528	(10.8)
remote small town	3,446	(7.5)	2,299	(7.9)	1,225	(7.6)	2,102	(7.5)	26,487	(5.8)
accessible rural area	8,762	(19.1)	5,201	(17.9)	2,834	(17.6)	4,963	(17.7)	96,023	(20.9)
remote rural area	4,093	(8.9)	2,494	(8.6)	1,367	(8.5)	2,284	(8.1)	41,107	(9.0)
Household socioeconomic position (NS-SEC) (main analysis)										
managers/professionals	12,715	(27.7)	7,130	(24.5)	3,675	(22.8)	7,139	(25.4)	161,594	(35.2)
intermediate	4,576	(10.0)	3,032	(10.4)	1,660	(10.3)	2,773	(9.9)	41,098	(9.0)
small employer	5,683	(12.4)	3,388	(11.7)	1,823	(11.3)	3,202	(11.4)	48,668	(10.6)
lower / technical	5,384	(11.7)	3,468	(11.9)	1,887	(11.7)	3,384	(12.0)	55,105	(12.0)
semi-skilled	7,362	(16.1)	4,957	(17.0)	2,754	(17.1)	4,731	(16.8)	57,865	(12.6)
unskilled	8,399	(18.3)	5,674	(19.5)	3,351	(20.8)	5,483	(19.5)	62,652	(13.7)
never worked / long term unemployed	954	(2.1)	770	(2.6)	483	(3.0)	750	(2.7)	7,069	(1.5)
not classified (e.g. students or age <16 in 2011)	773	(1.7)	662	(2.3)	483	(3.0)	635	(2.3)	24,846	(5.4)
Individual socioeconomic position (NS-SEC)										
managers/professionals	11,475	(25.0)	6,629	(22.8)	3,497	(21.7)	6,591	(23.5)	142,369	(31.0)
intermediate	5,905	(12.9)	3,713	(12.8)	1,973	(12.2)	3,403	(12.1)	57,624	(12.6)
small employer	4,764	(10.4)	2,988	(10.3)	1,633	(10.1)	2,796	(10.0)	37,694	(8.2)
lower / technical	4,385	(9.6)	2,973	(10.2)	1,711	(10.6)	2,930	(10.4)	44,486	(9.7)
semi-skilled	8,585	(18.7)	5,584	(19.2)	3,065	(19.0)	5,237	(18.6)	72,126	(15.7)
unskilled	8,233	(18.0)	5,835	(20.1)	3,457	(21.5)	5,560	(19.8)	61,140	(13.3)
never worked / long term unemployed	1,398	(3.0)	1,111	(3.8)	696	(4.3)	1,096	(3.9)	13,381	(2.9)
not classified (e.g. students or age <16 in 2011)	1,101	(2.4)	248	(0.9)	84	(0.5)	484	(1.7)	30,077	(6.6)
Individual socioeconomic position (Social Grade)										
A/B (higher / professional)	6,312	(13.8)	3,466	(11.9)	1,765	(11.0)	3,537	(12.6)	88,653	(19.3)
C1 (supervisory / clerical)	11,509	(25.1)	7,100	(24.4)	3,809	(23.6)	6,860	(24.4)	132,679	(28.9)
C2 (skilled manual)	10,502	(22.9)	5,965	(20.5)	3,140	(19.5)	6,075	(21.6)	114,567	(25.0)
D (semi-skilled / unskilled manual)	13,755	(30.0)	9,802	(33.7)	5,610	(34.8)	9,059	(32.2)	97,995	(21.4)
E (casual work / unemployed)	2,273	(5.0)	2,024	(7.0)	1,324	(8.2)	1,870	(6.7)	12,554	(2.7)
not classified (e.g. students or age <16 in 2011)	1,495	(3.3)	724	(2.5)	468	(2.9)	696	(2.5)	12,449	(2.7)

Table 1 – Population characteristics of people included in this study across in each of the four kidney disease cohorts and the general adult population

Abbreviations: eGFR, estimated glomerular filtration rate; AKD, acute kidney disease; NS-SEC, National Statistics Socioeconomic Classification; SIMD, Scottish Index of Multiple Deprivation; % refers to column % with the exception of age which is a standard deviation.

[1] Not classifiable from postcode in 0.1%

[2] Kidney severity thresholds also referred to in manuscript as eGFR <60, mild/early; eGFR <45, moderate; eGFR <30, advanced; AKD, acute kidney disease

Household socioeconomic position (NS-SEC)	SIMD 1 (most deprived)		SIMD 2		SIMD 3		SIMD 4		SIMD 5 (most affluent)	
	N	Column %	N	Column %	N	Column %	N	Column %	N	Column %
eGFR <60 cohort[1]	1,899		7,134		9,794		13,346		13,673	
managers/professionals	213	(11.2)	1,133	(15.9)	2,122	(21.7)	3,754	(28.1)	5,493	(40.2)
intermediate / small employer	258	(13.6)	1,234	(17.3)	2,222	(22.7)	3,356	(25.1)	3,189	(23.3)
lower / technical	254	(13.4)	928	(13.0)	1,298	(13.3)	1,563	(11.7)	1,341	(9.8)
semi-skilled	395	(20.8)	1,486	(20.8)	1,737	(17.7)	2,053	(15.4)	1,691	(12.4)
unskilled	624	(32.9)	2,033	(28.5)	2,023	(20.7)	2,190	(16.4)	1,529	(11.2)
never worked / long term unemployed	99	(5.2)	210	(2.9)	221	(2.3)	242	(1.8)	182	(1.3)
not classified	56	(2.9)	110	(1.5)	171	(1.7)	188	(1.4)	248	(1.8)
eGFR <45 cohort	1,253		4,841		6,387		8,332		8,268	
managers/professionals	131	(10.5)	700	(14.5)	1,247	(19.5)	2,071	(24.9)	2,981	(36.1)
intermediate / small employer	172	(13.7)	815	(16.8)	1,387	(21.7)	2,079	(25.0)	1,967	(23.8)
lower / technical	169	(13.5)	650	(13.4)	872	(13.7)	956	(11.5)	821	(9.9)
semi-skilled	278	(22.2)	1,010	(20.9)	1,177	(18.4)	1,380	(16.6)	1,112	(13.4)
unskilled	408	(32.6)	1,407	(29.1)	1,367	(21.4)	1,479	(17.8)	1,013	(12.3)
never worked / long term unemployed	57	(4.5)	165	(3.4)	198	(3.1)	202	(2.4)	148	(1.8)
not classified	38	(3.0)	94	(1.9)	139	(2.2)	165	(2.0)	226	(2.7)
eGFR <30 cohort	781		2,802		3,544		4,606		4,383	
managers/professionals	78	(10.0)	401	(14.3)	651	(18.4)	1,057	(22.9)	1,488	(33.9)
intermediate / small employer	109	(14.0)	459	(16.4)	740	(20.9)	1,137	(24.7)	1,038	(23.7)
lower / technical	95	(12.2)	361	(12.9)	465	(13.1)	539	(11.7)	427	(9.7)
semi-skilled	170	(21.8)	565	(20.2)	643	(18.1)	787	(17.1)	589	(13.4)
unskilled	261	(33.4)	843	(30.1)	825	(23.3)	830	(18.0)	592	(13.5)
never worked / long term unemployed	33	(4.2)	104	(3.7)	121	(3.4)	133	(2.9)	92	(2.1)
not classified	35	(4.5)	69	(2.5)	99	(2.8)	123	(2.7)	157	(3.6)
AKD cohort	1,378		4,810		6,130		7,934		7,845	
managers/professionals	162	(11.8)	709	(14.7)	1,282	(20.9)	2,025	(25.5)	2,961	(37.7)
intermediate / small employer	194	(14.1)	778	(16.2)	1,294	(21.1)	1,879	(23.7)	1,830	(23.3)
lower / technical	177	(12.8)	633	(13.2)	844	(13.8)	957	(12.1)	773	(9.9)
semi-skilled	291	(21.1)	1,020	(21.2)	1,110	(18.1)	1,305	(16.4)	1,005	(12.8)
unskilled	445	(32.3)	1,401	(29.1)	1,286	(21.0)	1,407	(17.7)	944	(12.0)
never worked / long term unemployed	63	(4.6)	175	(3.6)	175	(2.9)	195	(2.5)	142	(1.8)
not classified	46	(3.3)	94	(2.0)	139	(2.3)	166	(2.1)	190	(2.4)

Table 2 – Comparison of household (NS-SEC) and neighbourhood (SIMD) socioeconomic position across the four kidney disease cohorts

Abbreviations: eGFR, estimated glomerular filtration rate; AKD, acute kidney disease; NS-SEC, National Statistics Socioeconomic Classification; SIMD, Scottish Index of Multiple Deprivation

[1] Kidney severity thresholds are also referred to in manuscript as eGFR <60, mild/early; eGFR <45, moderate; eGFR <30, advanced; AKD, acute.

Presenting kidney disease cohort	Exposure group (vs managers/professionals)	Exposure Events / N at risk	Comparator Events / N at risk	Age, sex adjusted HR	(95% CI)	Age, sex, and SIMD adjusted (main analysis) HR	(95% CI)	Age, sex, SIMD and morbidity adjusted [2] HR	(95% CI)	Age, sex, SIMD and morbidity adjusted and long-term sick excluded HR	(95% CI)
eGFR<60[1]	Unskilled job	2894/8399	3480/12715	**1.29**	(1.23-1.36)	**1.26**	(1.19-1.32)	**1.21**	(1.15-1.27)	**1.20**	(1.14-1.27)
eGFR<60	Never worked / unemployed	436/954	3480/12715	**1.83**	(1.65-2.02)	**1.77**	(1.60-1.96)	**1.79**	(1.62-1.98)	**1.74**	(1.57-1.94)
eGFR<45	Unskilled job	2816/5674	3237/7130	**1.11**	(1.05-1.16)	**1.08**	(1.03-1.14)	**1.07**	(1.02-1.13)	**1.07**	(1.02-1.13)
eGFR<45	Never worked / unemployed	465/770	3237/7130	**1.42**	(1.29-1.56)	**1.39**	(1.26-1.54)	**1.42**	(1.28-1.56)	**1.37**	(1.23-1.52)
eGFR<30	Unskilled job	2122/3351	2232/3675	**1.04**	(0.98-1.11)	**1.02**	(0.96-1.08)	**1.01**	(0.95-1.07)	**1.01**	(0.95-1.08)
eGFR<30	Never worked / unemployed	335/483	2232/3675	**1.21**	(1.08-1.36)	**1.18**	(1.05-1.33)	**1.22**	(1.09-1.38)	**1.19**	(1.05-1.34)
AKD	Unskilled job	3103/5483	3548/7139	**1.09**	(1.05-1.14)	**1.05**	(1.00-1.10)	**1.05**	(1.00-1.10)	**1.04**	(0.99-1.10)
AKD	Never worked / unemployed	436/750	3548/7139	**1.16**	(1.05-1.28)	**1.12**	(1.01-1.24)	**1.17**	(1.05-1.29)	**1.12**	(1.01-1.25)

Table 3 – Long term (ten year) mortality based on household socioeconomic position (NS-SEC) in each of the four kidney disease cohorts

Abbreviations: eGFR, estimated glomerular filtration rate; AKD, acute kidney disease; HR, hazard ratio; NS-SEC, National Statistics Socioeconomic Classification; SIMD, Scottish Index of Multiple Deprivation

[1] Kidney severity thresholds also referred to in manuscript as eGFR <60, mild/early; eGFR <45, moderate; eGFR <30, advanced; AKD, acute kidney disease

[2] Morbidities were regarded as a mediators, but were adjusted in a sensitivity analysis. These included history of cancer, chronic obstructive pulmonary disease, coronary heart disease, diabetes, hypertension, liver disease, peripheral arterial disease, stroke

Figure 1 – Linkage and development of study population

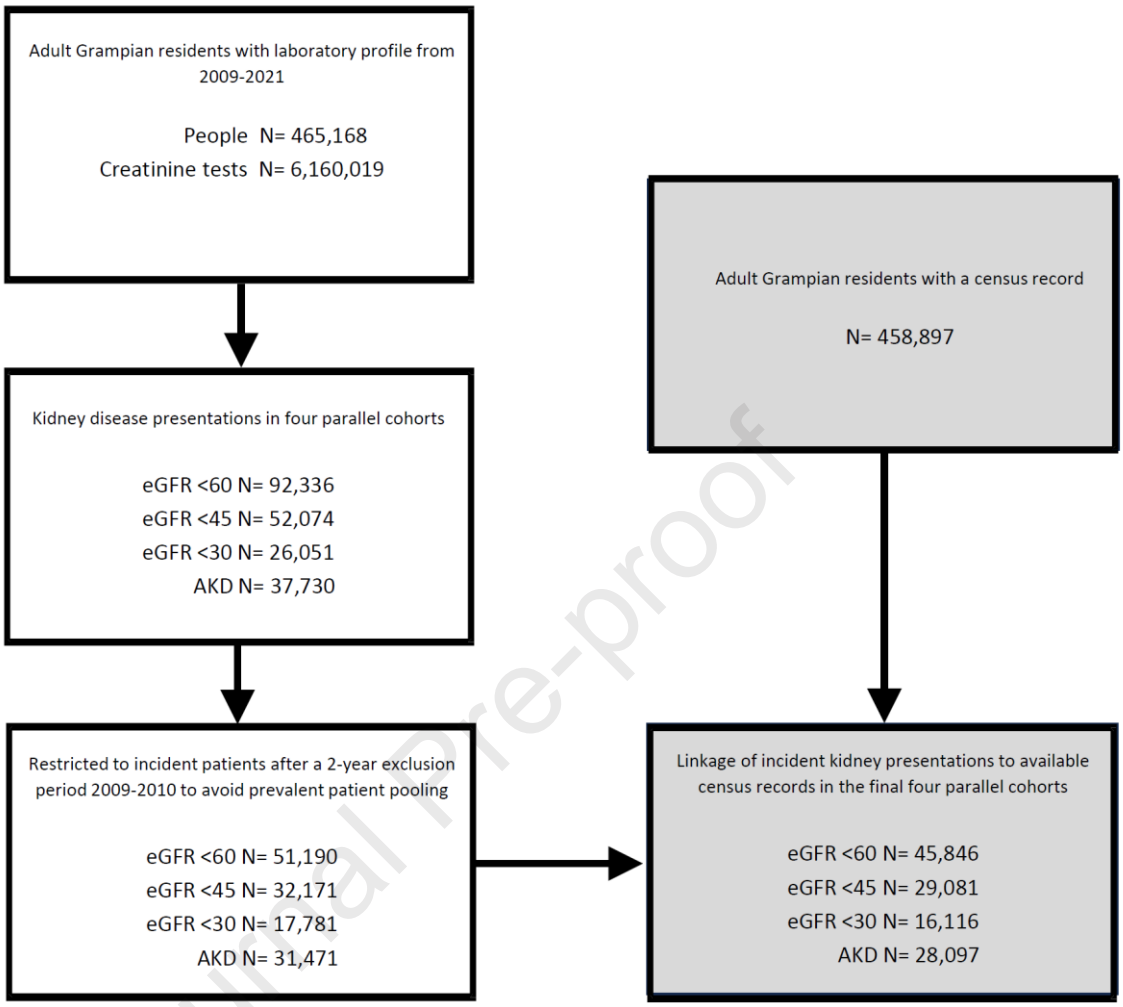


Figure 2 – Living circumstances of people presenting with early kidney disease based on household socioeconomic position (NS-SEC). Case-mix adjusted odds ratios depicted with black diamonds, with 95% confidence intervals for unskilled vs professionals (pink) and unemployed vs professionals (purple) households.

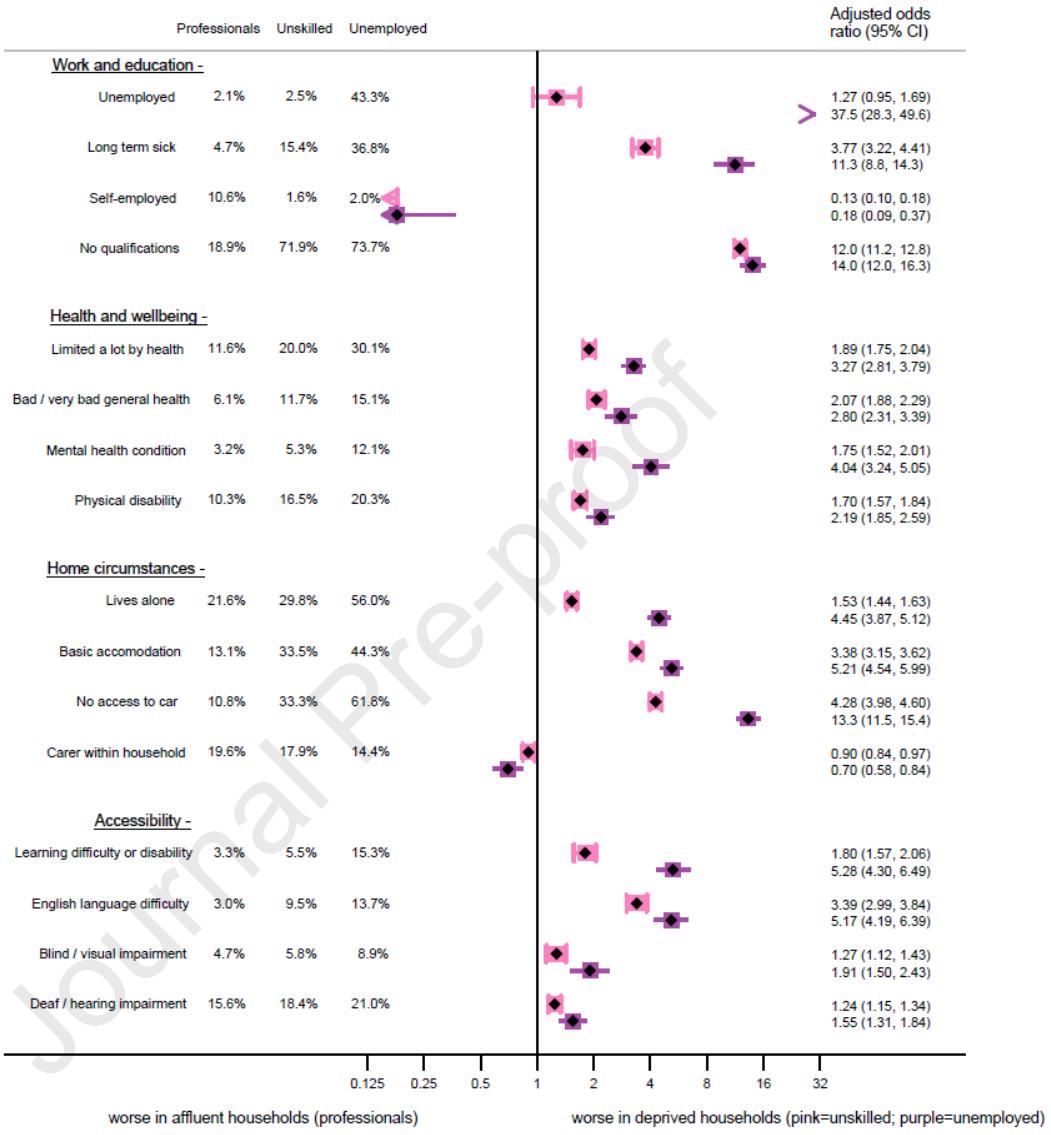


Figure 3 – Living circumstances of people presenting with early kidney disease based on neighbourhood deprivation quintile (SIMD). Case-mix adjusted odds ratios depicted with black diamonds, with 95% confidence intervals for most deprived vs most affluent neighbourhood areas.

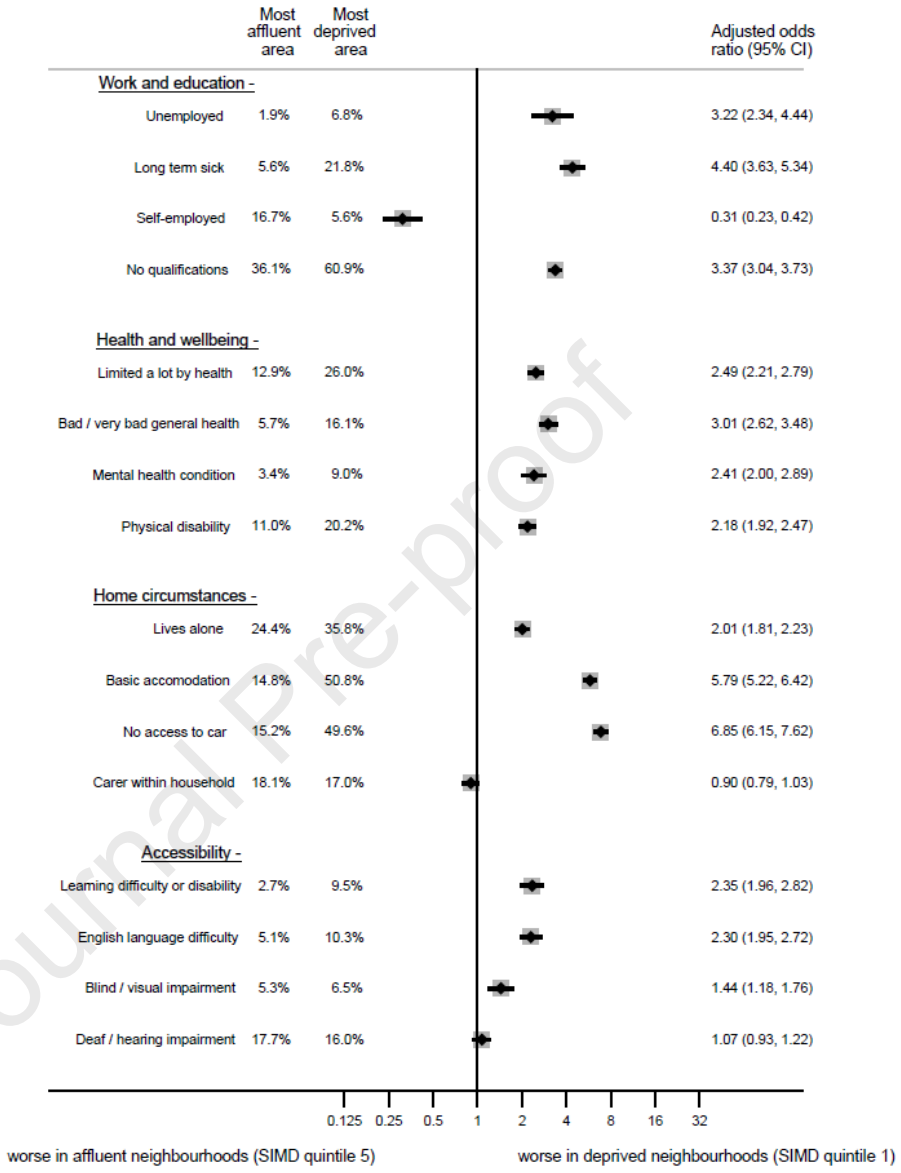
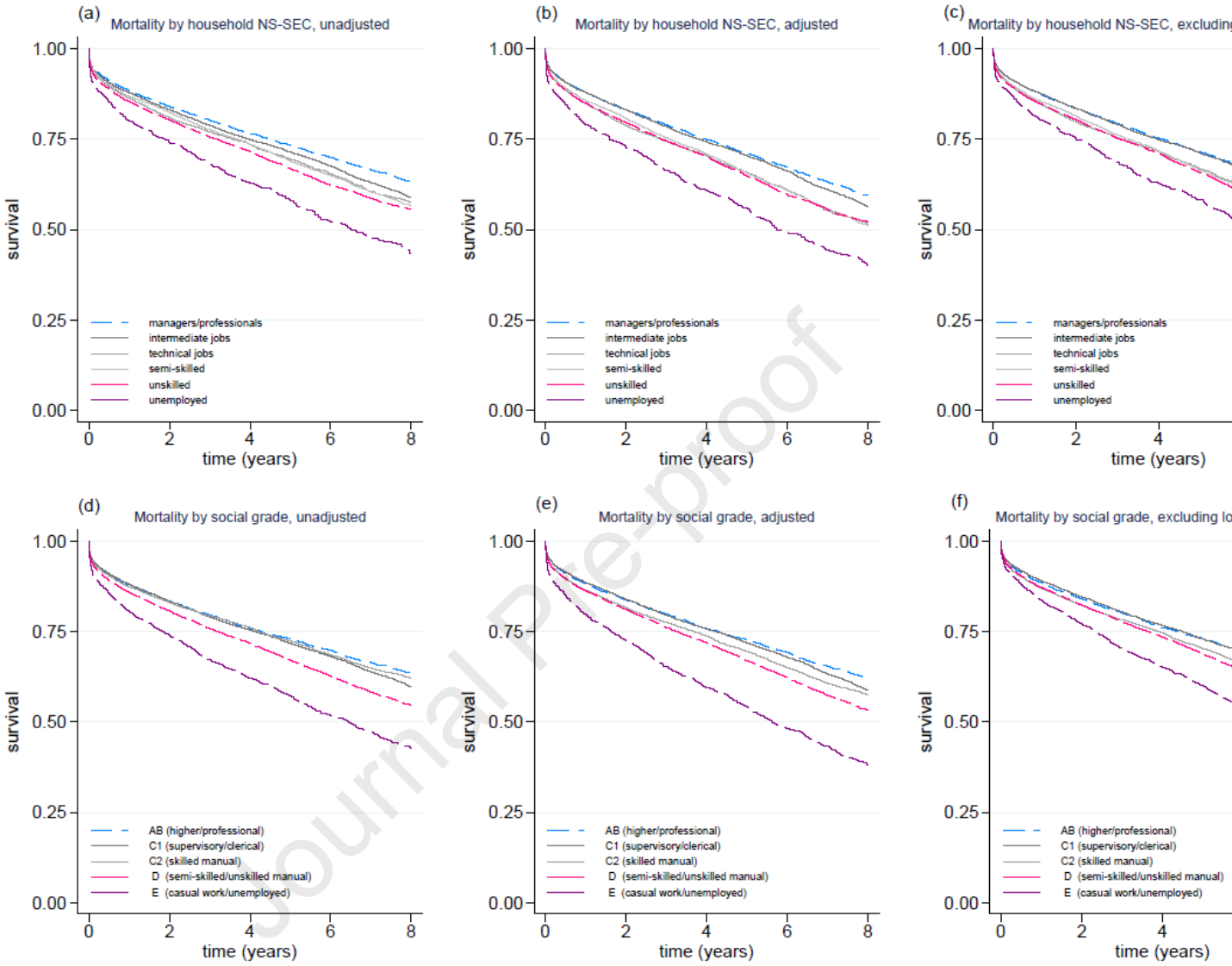


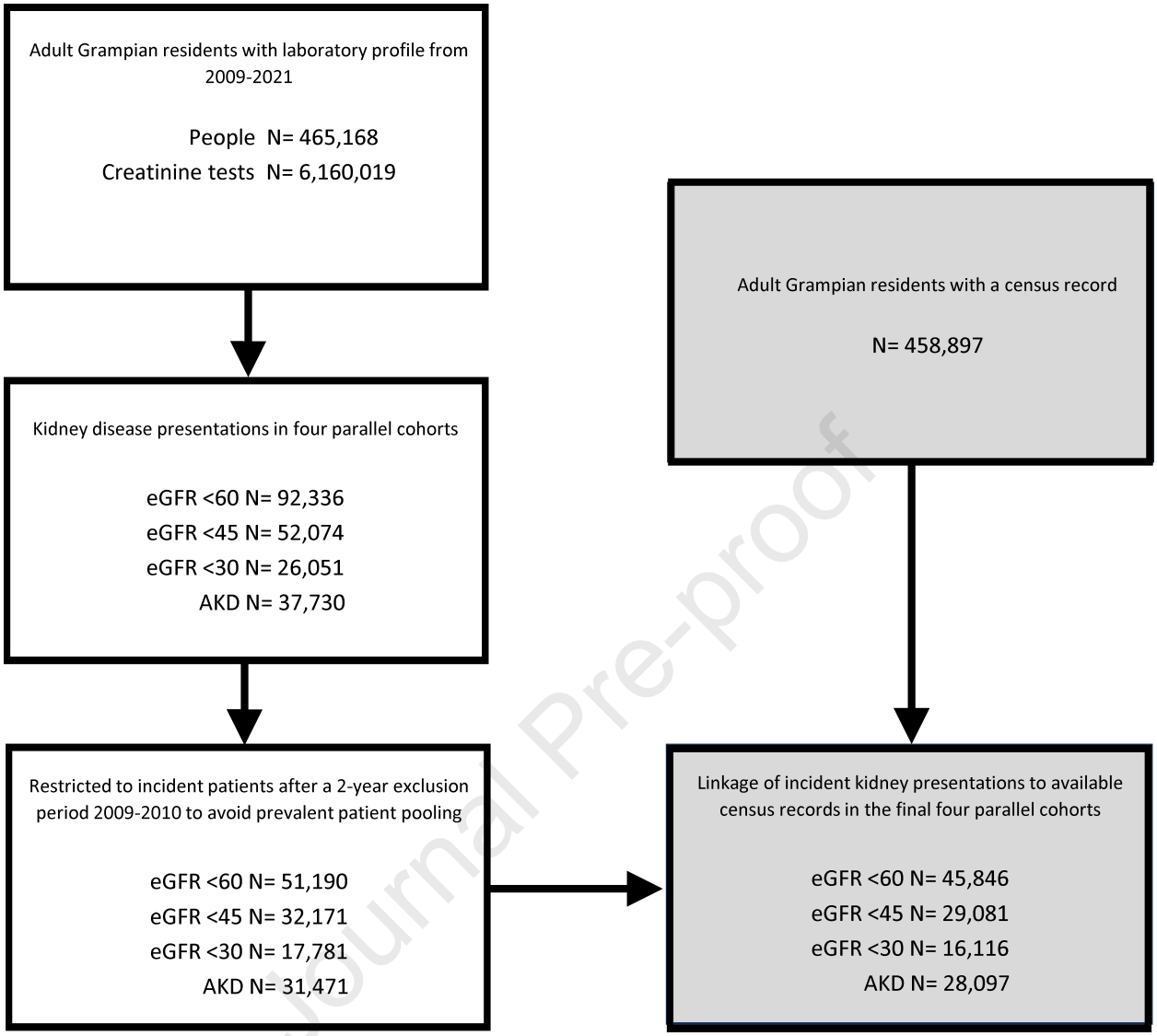
Figure 4 – Age and sex adjusted mortality hazard ratios for people presenting with early kidney disease eGFR <60 according to household (NS-SEC) and neighbourhood (SIMD) socioeconomic position

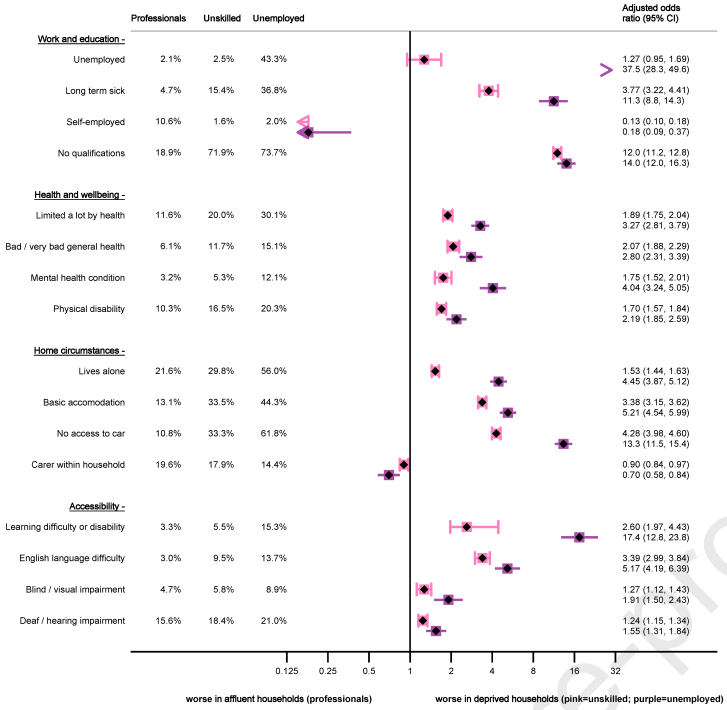
Note: Bold type denotes p<0.05.

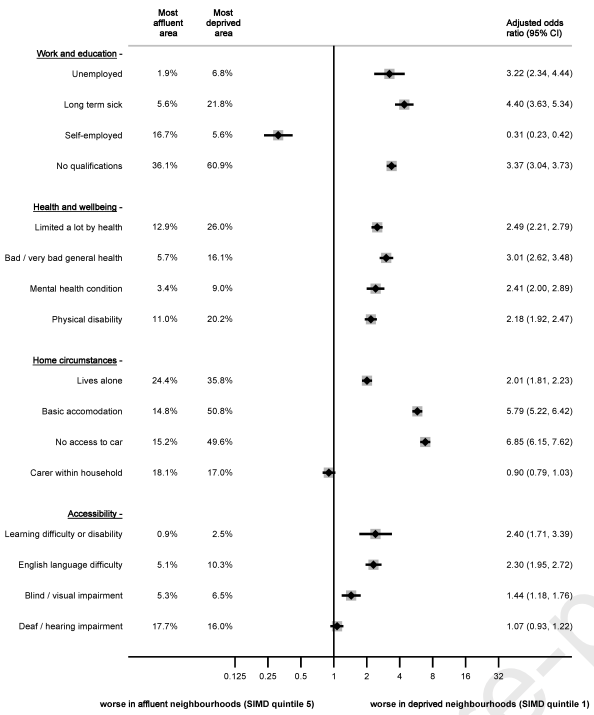
	Neighbourhood deprivation quintile				
Household socioeconomic status	**5 (affluent)**	**4**	**3**	**2**	**1 (deprived)**
managers/professionals	1.00	1.06	**1.18**	**1.14**	**1.31**
intermediate/small employer	**1.16**	**1.16**	**1.11**	**1.26**	**1.39**
lower supervisory/technical	**1.23**	**1.23**	**1.24**	**1.29**	**1.91**
semi-skilled	**1.29**	**1.24**	**1.27**	**1.36**	**1.65**
unskilled	**1.36**	**1.29**	**1.37**	**1.41**	**1.70**
never worked/unemployed	**1.98**	**1.89**	**1.87**	**2.04**	**2.06**

Figure 5 – Long-term mortality of people presenting with early kidney disease (eGFR <60) by household (NS-SEC) and individual (Social Grade) socioeconomic position









	Neighbourhood deprivation quintile				
Household socioeconomic status	5 (affluent)	4	3	2	1 (deprived)
managers/professionals	1.00	1.06	1.18	1.14	1.31
intermediate/small employer	1.16	1.16	1.11	1.26	1.39
lower supervisory/technical	1.23	1.23	1.24	1.29	1.91
semi-skilled	1.29	1.24	1.27	1.36	1.65
unskilled	1.36	1.29	1.37	1.41	1.70
never worked/unemployed	1.98	1.89	1.87	2.04	2.06

Colour key
1.0
1.1
1.2
1.3
1.4
1.5