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

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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, and 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.

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Lay Summary

Existing research looking into the equity of kidney health and care frequently suffers from insufficient detail by describing the neighborhoods 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 of 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 access to a car, language, and communication. Collectively, these challenges may affect their opportunities to have good kidney health and to live well.

People in deprived communities develop kidney disease earlier, experience less proactive care, progress more rapidly toward kidney failure, and die younger.[1,2] Although literature on the equity of access to kidney care

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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 underserved. Where misaligned, well-intended interventions risk broadening rather than narrowing inequities by failing to reach their intended groups or by unintentionally deprioritizing 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 underserved people.[2,36–39] For instance, population area-level studies of neighborhood deprivation may be sufficient to restate the inequity that we already know but lack the finer detail for understanding intersecting relationships and mechanisms. Although 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 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 10 years, covering information on individuals and their household composition, employment, education, qualifications, ethnicity, language, well-being, and living circumstances. Our aims were 2-fold: (i) to assess in a general population of people presenting with kidney disease, whether household socioeconomic status is associated with subsequent mortality independent of neighborhood measures of deprivation; and (ii) to understand how the living circumstances of people presenting with kidney disease vary according to household socioeconomic status, neighborhood, and kidney disease severity.

METHODS

Linkage of Grampian Laboratory Outcomes Morbidity and Mortality Study population health data and Scottish census data (GLOMMS-CORE)

The Grampian Laboratory Outcomes Morbidity and Mortality Study (GLOMMS) features 20 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 health care but has the highest mortality in Western Europe and a widening health gap between the most and least deprived areas.[46] Although Grampian compares favorably with other regions of Scotland, areas of both affluence and deprivation are dispersed, and Grampian contains both some of the most deprived and affluent neighborhoods 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—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 4 parallel kidney cohorts of people living in Grampian with incident kidney presentations on the basis of their population laboratory results from 2011 to 2021. This is summarized in Figure 1, as well as in our previous work.[2] In each of the 4 cohorts, adults 18 years or older 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 Collaboration (CKD-EPI 2009 without correction for race) estimated glomerular filtration rate (eGFR) of <60, <45, and <30 ml/min per 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 aligned algorithm. All kidney-related definitions have been implemented and replicated in previous work, with code and coding dictionaries available.[48,49] As

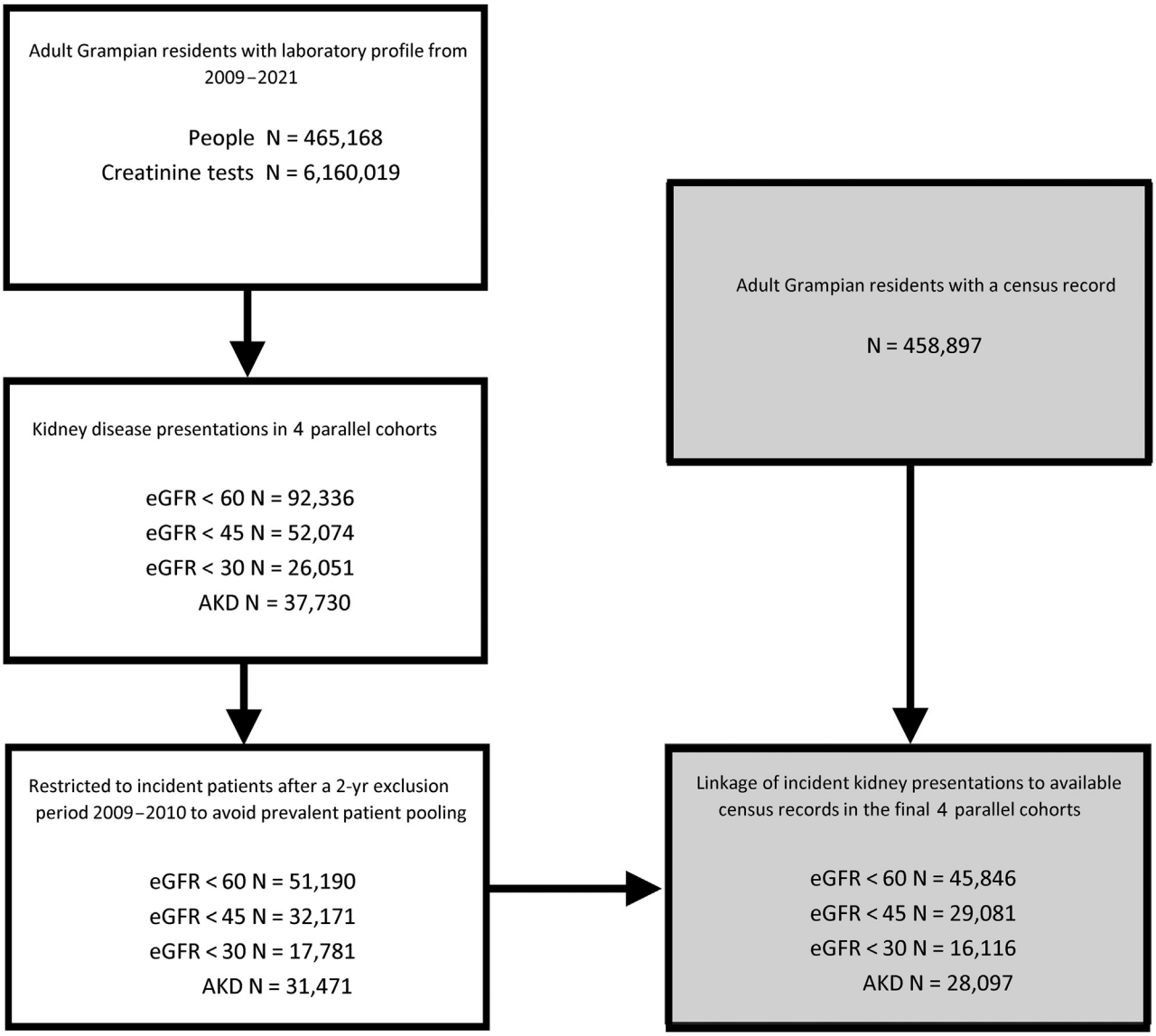

Figure 1 | Linkage and development of the study population. eGFR, estimated glomerular filtration rate.

described elsewhere, using 2 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 on the basis of 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 2-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 4 parallel kidney cohorts were then linked to their census records to form the study populations.

Exposures and comparators: household and neighborhood 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 recognizes that an individual's circumstances may be less relevant to their socioeconomic position than those of 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 is conventionally collapsed into categories of people with similar socioeconomic position. In Box 1, we have listed these categories with example occupations.[51–54] Categories 6 to 8 are sometimes referred to as

Box 1 | Categories of the Household National Statistics Socio-economic Classification (NS-SEC) and example occupations

Category	NS-SEC definition	Example occupations
1 and 2	Managers and professionals	Lawyers, architects, medical doctors, chief executives, economists, social workers, nurses, journalists, retail managers, teachers
3 and 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	Semiroutine ("semiskilled" occupations)	Traffic wardens, receptionists, shelf-stackers, care workers, telephone salespersons
7	Routine ("unskilled" or casual work)	Bar staff, cleaners, laborers, lorry drivers
8	Never worked or long-term unemployed	No regular employment

"working class."[52] In our analyses, we compared "unskilled" and "unemployed" categories with a reference "affluent" category of "managers and professionals."

For the neighborhood 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 neighborhood area across 7 domains of income, employment, education, health, access to services, crime, and housing. SIMD is traditionally reported within quintiles ranging from neighborhoods within the most deprived 20% of Scotland (quintile 1) to neighborhoods within the most affluent 20% of Scotland (quintile 5).

In sensitivity analyses, we also used NS-SEC for the individual rather than household category and individual (5 levels, A–E) social grade category. Social grade is a less commonly used alternative measure developed originally from market research and approximated from census responses by 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), and visual and hearing impairment.

Additional variables from the GLOMMS health data set

Available variables included age, sex, comorbidities, prescribed medications, monitoring and results of blood and urine tests, dates and outcomes of emergency department, and outpatient and inpatient attendances. Comorbidities in the analyses were 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 Government 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 January 1, 2021 (i.e., up to 10 years).

Statistical analyses

Across each of the 4 parallel cohorts of incident kidney presentations (at eGFR $<$ 60 ml/min per 1.73 m^2, eGFR $<$ 45 ml/min per 1.73 m^2, eGFR $<$ 30 ml/min per 1.73 m^2, and AKD), we described cohort characteristics, SIMD (neighborhood) quintiles, and household NS-SEC categories. We cross-tabulated household NS-SEC categories against SIMD quintiles to establish the extent of overlap between household and neighborhood deprivation measures. We described social and living characteristics of people in deprived and affluent household and neighborhood categories. Finally, we reported the association household-level deprivation with long-term mortality independent of neighborhood deprivation.

For each of the 4 cohorts, to understand how living circumstances varied by household ("unskilled" and "unemployed" households vs. "professionals") and neighborhood (most deprived vs. most affluent quintile), we used multivariable logistic regression adjusting for age and sex to estimate the 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, sex, and neighborhood SIMD quintile. In addition, 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 whether 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 per 1.73 m^2) to explore the joint relationships of household, neighborhood 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 the household NS-SEC and the neighborhood SIMD quintile. We tested for interaction significance using a likelihood ratio test of nested models. In supplementary analyses in the Supplementary Material, 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 those on long-term sick leave as described above. All analyses were performed using Stata/SE 17 (StataCorp LLC),[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 ml/min per 1.73 m^2, eGFR $<$ 45 ml/min per 1.73 m^2, eGFR $<$ 30 ml/min per 1.73 m^2, and AKD, leading to 45,846, 29,081, 16,116, and 28,097 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 4 kidney cohorts with the underlying Grampian population (Table 1). The mean age was over 70 years compared with just below 50 years for the general population; 99% were White and 97% born in the United Kingdom as 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 presentations of kidney disease were expressed as a proportion of people who completed the census, 10% of census respondents had a presentation of early kidney disease (eGFR $<$ 60 ml/min per 1.73 m^2), 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 and neighborhood socioeconomic positions

In all kidney cohorts, compared to deprived neighborhoods (SIMD quintile 1), a higher proportion of people living in affluent neighborhoods (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 household categories and neighborhood deprivation categories, such that in all areas health care professionals who look after those with kidney disease would see people from all social backgrounds in their clinics (Table 2; Supplementary Table S3).

Individual social and living circumstances

People presenting with early kidney disease who were from unskilled or unemployed households had higher age- and sex-adjusted odds of reporting adverse living circumstances than did 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 well-being, 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 circumstances were similarly increased in those living in more deprived versus affluent neighborhoods (Figure 3). Figures 2 and 3 describe these patterns for those presenting with early kidney disease, and Supplementary Tables S4 and S5 indicate 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 with people in professional households, people with newly presenting early kidney disease in unskilled or unemployed households had increased age-, sex-, neighborhood-adjusted hazards of mortality (respective hazard ratios [95% confidence intervals] 1.26 [1.19–1.32] and 1.77 [1.60–1.96]), with adjustment for neighborhood 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 in people with more advanced kidney disease or AKD. 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 neighborhood deprivation is provided as a cross-tabulated heatmap in Figure 4 (and Supplementary Figure S1 for social grade). An interaction term for household and neighborhood was not significant ($P = 0.54$), consistent with separate independent associations of household and neighborhood area with mortality. Thus, those in unskilled or unemployed households experienced higher mortality than did those in professional households, and even higher mortality if they also lived in a deprived neighborhood (SIMD quintile 1). Similarly, although people in professional households had the lowest mortality overall, they were still more likely to die if they lived in a deprived neighborhood. Moreover, the pattern of attenuating excess mortality for disadvantaged neighborhoods and households at later stages of kidney disease (described in Table 3) was evident when cross-tabulated in heatmaps across different kidney severity stages (Supplementary Figure S2).

Table 1 | Population characteristics of people included in this study in each of the 4 kidney disease cohorts and the general adult population

Characteristic	eGFR < 60 ml/min per 1.73 m^2[a]	eGFR < 45 ml/min per 1.73 m^2	eGFR < 30 ml/min per 1.73 m^2	AKD	All adults
N (with complete data)	45,846	29,081	16,116	28,097	458,897
Age at presentation, yr	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)	8683 (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 United Kingdom	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)	8268 (28.4)	4383 (27.2)	7845 (27.9)	154,457 (33.7)
4	13,346 (29.1)	8332 (28.7)	4606 (28.6)	7934 (28.2)	130,562 (28.5)
3	9794 (21.4)	6387 (22.0)	3544 (22.0)	6130 (21.8)	91,824 (20.0)
2	7134 (15.6)	4841 (16.6)	2802 (17.4)	4810 (17.1)	63,023 (13.7)
1 (most deprived)	1899 (4.1)	1253 (4.3)	781 (4.8)	1378 (4.9)	19,031 (4.1)
Rural home location[b]					
Urban	25,298 (55.2)	16,469 (56.6)	9210 (57.1)	16,247 (57.8)	245,752 (53.6)
Accessible small town	4181 (9.1)	2583 (8.9)	1458 (9.0)	2468 (8.8)	49,528 (10.8)
Remote small town	3446 (7.5)	2299 (7.9)	1225 (7.6)	2102 (7.5)	26,487 (5.8)
Accessible rural area	8762 (19.1)	5201 (17.9)	2834 (17.6)	4963 (17.7)	96,023 (20.9)
Remote rural area	4093 (8.9)	2494 (8.6)	1367 (8.5)	2284 (8.1)	41,107 (9.0)
Household socioeconomic position (NS-SEC) (main analysis)					
Managers/professionals	12,715 (27.7)	7130 (24.5)	3675 (22.8)	7139 (25.4)	161,594 (35.2)
Intermediate	4576 (10.0)	3032 (10.4)	1660 (10.3)	2773 (9.9)	41,098 (9.0)
Small employer	5683 (12.4)	3388 (11.7)	1823 (11.3)	3202 (11.4)	48,668 (10.6)
Lower/technical	5384 (11.7)	3468 (11.9)	1887 (11.7)	3384 (12.0)	55,105 (12.0)
Semi-skilled	7362 (16.1)	4957 (17.0)	2754 (17.1)	4731 (16.8)	57,865 (12.6)
Unskilled	8399 (18.3)	5674 (19.5)	3351 (20.8)	5483 (19.5)	62,652 (13.7)
Never worked/long-term unemployed	954 (2.1)	770 (2.6)	483 (3.0)	750 (2.7)	7069 (1.5)
Not classified (e.g., students or age < 16 yr 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)	6629 (22.8)	3497 (21.7)	6591 (23.5)	142,369 (31.0)
Intermediate	5905 (12.9)	3713 (12.8)	1973 (12.2)	3403 (12.1)	57,624 (12.6)
Small employer	4764 (10.4)	2988 (10.3)	1633 (10.1)	2796 (10.0)	37,694 (8.2)
Lower/technical	4385 (9.6)	2973 (10.2)	1711 (10.6)	2930 (10.4)	44,486 (9.7)
Semiskilled	8585 (18.7)	5584 (19.2)	3065 (19.0)	5237 (18.6)	72,126 (15.7)
Unskilled	8233 (18.0)	5835 (20.1)	3457 (21.5)	5560 (19.8)	61,140 (13.3)
Never worked/long-term unemployed	1398 (3.0)	1111 (3.8)	696 (4.3)	1096 (3.9)	13,381 (2.9)
Not classified (e.g., students or age < 16 yr in 2011)	1101 (2.4)	248 (0.9)	84 (0.5)	484 (1.7)	30,077 (6.6)
Individual socioeconomic position (social grade)					
A/B (higher/professional)	6312 (13.8)	3466 (11.9)	1765 (11.0)	3537 (12.6)	88,653 (19.3)
C1 (supervisory/clerical)	11,509 (25.1)	7100 (24.4)	3809 (23.6)	6860 (24.4)	132,679 (28.9)
C2 (skilled manual)	10,502 (22.9)	5965 (20.5)	3140 (19.5)	6075 (21.6)	114,567 (25.0)
D (semiskilled/unskilled manual)	13,755 (30.0)	9802 (33.7)	5610 (34.8)	9059 (32.2)	97,995 (21.4)
E (casual work/unemployed)	2273 (5.0)	2024 (7.0)	1324 (8.2)	1870 (6.7)	12,554 (2.7)
Not classified (e.g., students or age < 16 yr in 2011)	1495 (3.3)	724 (2.5)	468 (2.9)	696 (2.5)	12,449 (2.7)

AKD, acute kidney disease; eGFR, estimated glomerular filtration rate; NS-SEC, National Statistics Socio-economic Classification; SIMD, Scottish Index of Multiple Deprivation.
[a]Kidney severity thresholds also referred to in the article as eGFR < 60 ml/min per 1.73 m^2, mild/early; eGFR < 45 ml/min per 1.73 m^2, moderate; eGFR < 30 ml/min per 1.73 m^2, advanced; AKD.
[b]Not classifiable from postcode in 0.1%.
Data are expressed as mean ± SD or n (%).

Table 2 | Comparison of household (NS-SEC) and neighborhood (SIMD) socioeconomic positions across the 4 kidney disease cohorts

Household socioeconomic position (NS-SEC)	SIMD quintile 1 (most deprived)		SIMD quintile 2		SIMD quintile 3		SIMD quintile 4		SIMD quintile 5 (most affluent)	
	n	Column %	n	Column %	n	Column %	n	Column %	n	Column %
eGFR < 60 ml/min per 1.73 m^2 cohort[a]	1899		7134		9794		13,346		13,673	
Managers/professionals	213	11.2	1133	15.9	2122	21.7	3754	28.1	5493	40.2
Intermediate/small employer	258	13.6	1234	17.3	2222	22.7	3356	25.1	3189	23.3
Lower/technical	254	13.4	928	13.0	1298	13.3	1563	11.7	1341	9.8
Semiskilled	395	20.8	1486	20.8	1737	17.7	2053	15.4	1691	12.4
Unskilled	624	32.9	2033	28.5	2023	20.7	2190	16.4	1529	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 ml/min per 1.73 m^2 cohort	1253		4841		6387		8332		8268	
Managers/professionals	131	10.5	700	14.5	1247	19.5	2071	24.9	2981	36.1
Intermediate/small employer	172	13.7	815	16.8	1387	21.7	2079	25.0	1967	23.8
Lower/technical	169	13.5	650	13.4	872	13.7	956	11.5	821	9.9
semiskilled	278	22.2	1010	20.9	1177	18.4	1380	16.6	1112	13.4
Unskilled	408	32.6	1407	29.1	1367	21.4	1479	17.8	1013	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 ml/min per 1.73 m^2 cohort	781		2802		3544		4606		4383	
Managers/professionals	78	10.0	401	14.3	651	18.4	1057	22.9	1488	33.9
Intermediate/small employer	109	14.0	459	16.4	740	20.9	1137	24.7	1038	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	1378		4810		6130		7934		7845	
Managers/professionals	162	11.8	709	14.7	1282	20.9	2025	25.5	2961	37.7
Intermediate/small employer	194	14.1	778	16.2	1294	21.1	1879	23.7	1830	23.3
Lower/technical	177	12.8	633	13.2	844	13.8	957	12.1	773	9.9
semiskilled	291	21.1	1020	21.2	1110	18.1	1305	16.4	1005	12.8
Unskilled	445	32.3	1401	29.1	1286	21.0	1407	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

AKD, acute kidney disease; eGFR, estimated glomerular filtration rate; NS-SEC, National Statistics Socio-economic Classification; SIMD, Scottish Index of Multiple Deprivation.
[a]Kidney severity thresholds are also referred to in the article as eGFR < 60 ml/min per 1.73 m^2, mild/early; eGFR < 45 ml/min per 1.73 m^2, moderate; eGFR < 30 ml/min per 1.73 m^2, advanced; AKD.

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 versus those categorized in other household categories (gray). 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 were limited 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 neighborhood socioeconomic deprivation are associated with poorer health outcomes—physical, social, and mental well-being. People with early kidney disease who lived in *either* deprived households or deprived neighborhoods experienced higher mortality, but those who experienced *both* household and neighborhood deprivation were the most disadvantaged. Moreover, household and neighborhood classifications often did not match, which has particular

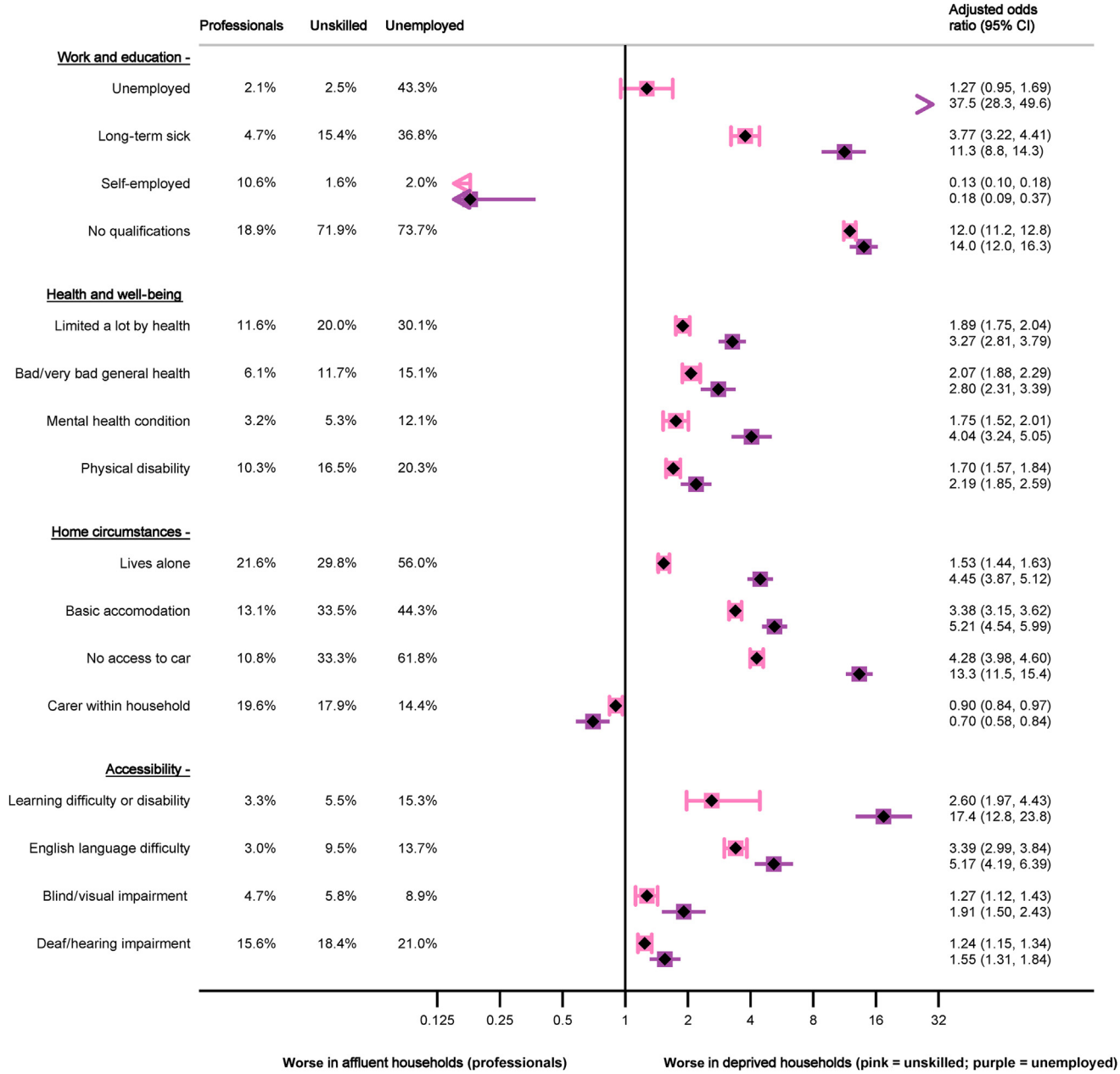

Figure 2 | Living circumstances of people presenting with early kidney disease according to household socioeconomic position (National Statistics Socio-economic Classification). Case-mix–adjusted odds ratios are depicted with black diamonds, along with 95% confidence intervals (CIs) for unskilled versus professionals (pink) and unemployed versus professionals (purple) households.

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 well-being, including physical health, mental health, and degree of limitation; factors that may affect navigation of health care 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 neighborhood areas. We also identified a substantial minority of people with English language difficulties and learning, visual, and hearing

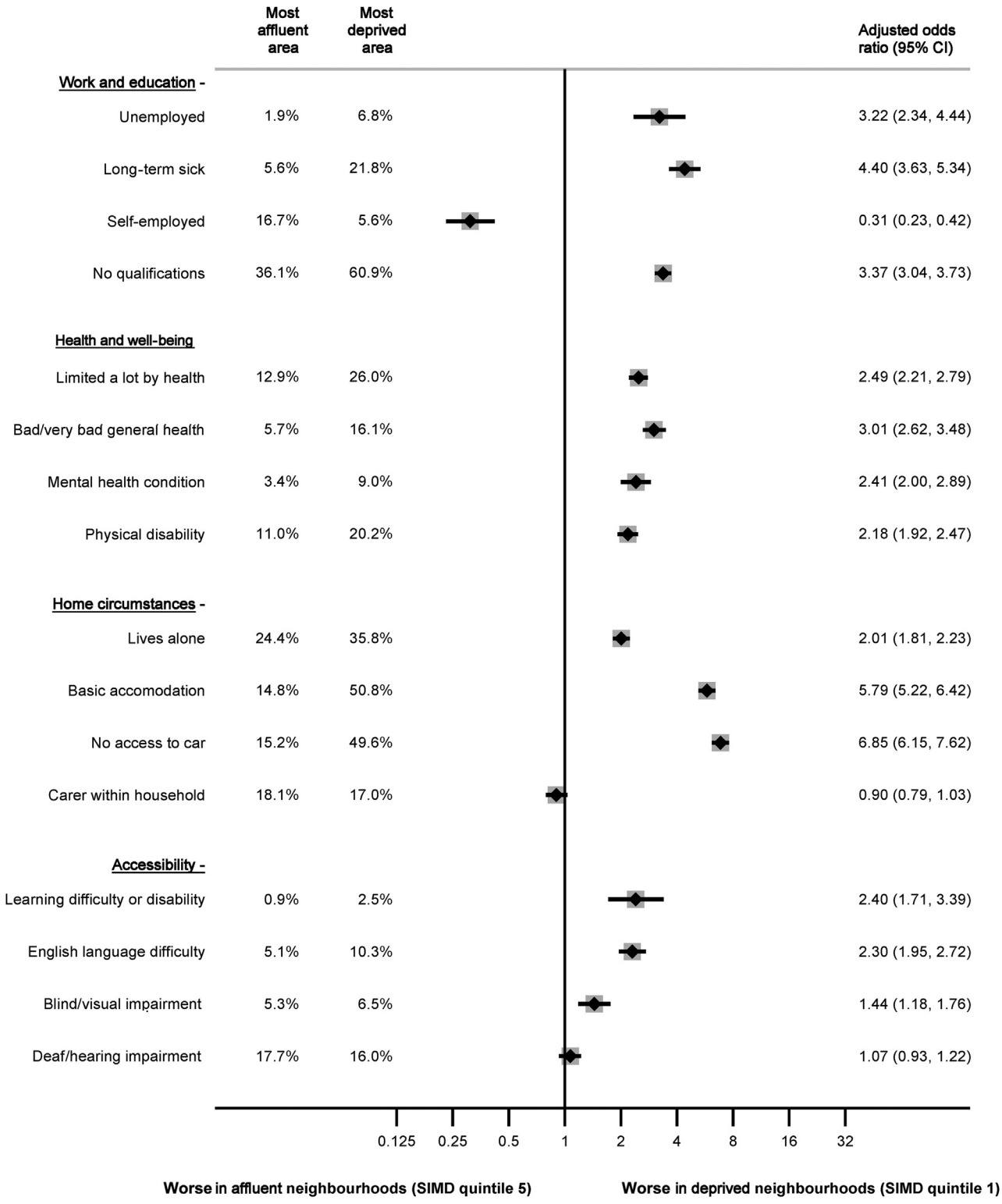

Figure 3 | Living circumstances of people presenting with early kidney disease according to neighborhood deprivation (Scottish Index of Multiple Deprivation [SIMD]) quintile. Case-mix adjusted odds ratios are depicted with black diamonds, along with 95% confidence intervals (CIs) for most deprived versus most affluent neighborhood areas.

impairments. These factors were related to household and neighborhood socioeconomic positions 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.,

Table 3 | Long-term (10-yr) mortality based on household socioeconomic position (NS-SEC) in each of the 4 kidney disease cohorts

Presenting kidney disease cohort	Exposure group (vs. managers/ professionals)	Exposure: no. of events/no. at risk	Comparator: no. of events/no. at risk	Age and sex adjusted		Age, sex, and SIMD adjusted (main analysis)		Age, sex, SIMD, and morbidity adjusted[a]		Age, sex, SIMD, and morbidity adjusted and long-term sick excluded	
				HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
eGFR < 60 ml/min per 1.73 m^2[b]	Unskilled job	2894/8399	3480/12,715	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 ml/min per 1.73 m^2	Never worked/ unemployed	436/954	3480/12,715	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 ml/min per 1.73 m^2	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 ml/min per 1.73 m^2	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 ml/min per 1.73 m^2	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 ml/min per 1.73 m^2	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

AKD, acute kidney disease; CI, confidence interval; eGFR, estimated glomerular filtration rate; HR, hazard ratio; NS-SEC, National Statistics Socio-economic Classification; SIMD, Scottish Index of Multiple Deprivation.
[a]Morbidities were regarded as a mediator 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, and stroke.
[b]Kidney severity thresholds also referred to in the article as eGFR < 60 ml/min per 1.73 m^2, mild/early; eGFR < 45 ml/min per 1.73 m^2, moderate; eGFR < 30 ml/min per 1.73 m^2, advanced; AKD.

Household socioeconomic status	Neighborhood deprivation quintile: 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

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Figure 4 | Age- and sex-adjusted mortality hazard ratios for people presenting with early kidney disease (estimated glomerular filtration rate < 60 ml/min per 1.73 m^2) according to household (National Statistics Socio-economic Classification) and neighborhood (Scottish Index of Multiple Deprivation) socioeconomic positions. Note: Boldface denotes $P < .05$.

self-rated measures of well-being), 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

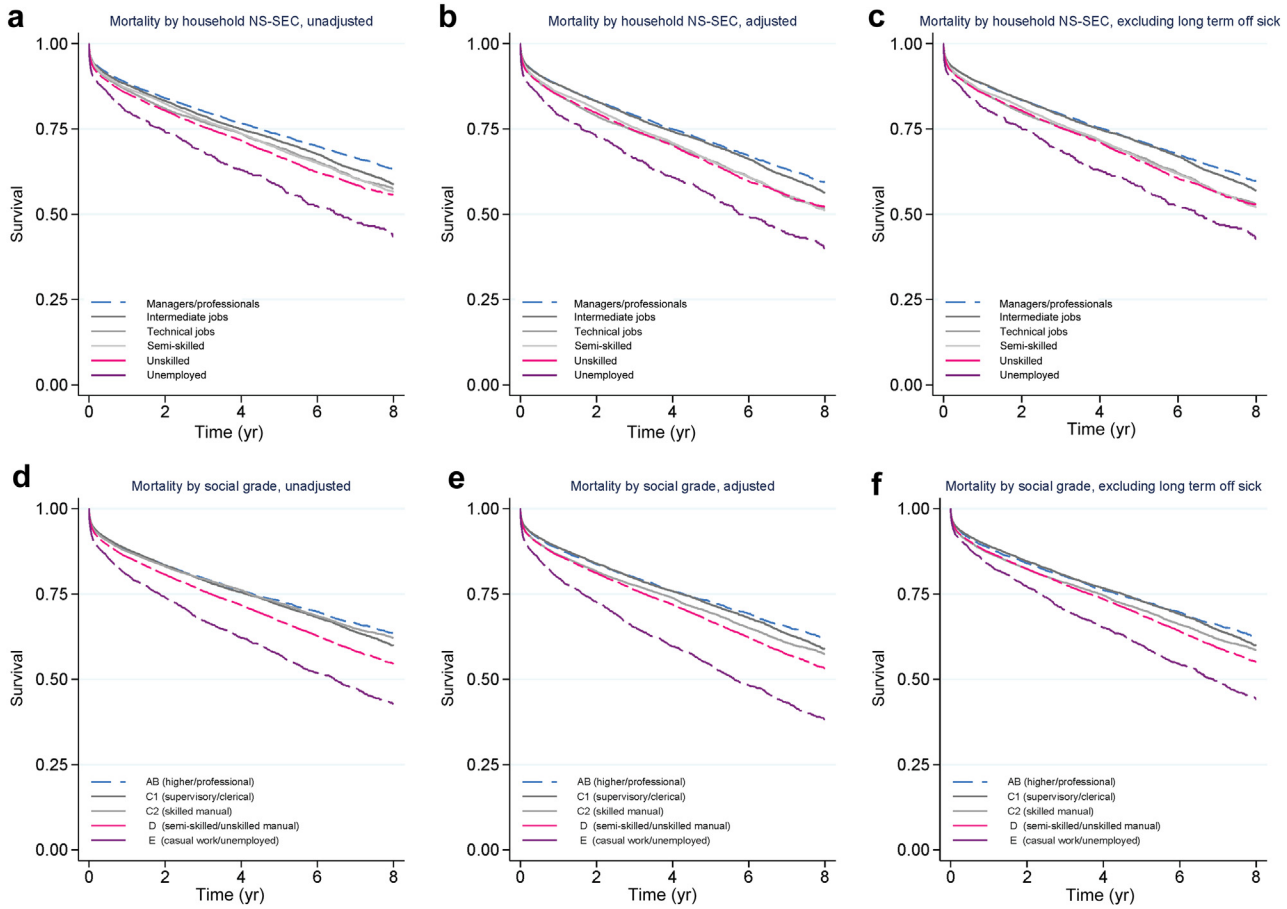

Figure 5 | Long-term mortality of people presenting with early kidney disease (estimated glomerular filtration rate [eGFR] < 60 ml/min per 1.73 m^2) according to household (National Statistics Socio-economic Classification [NS-SEC]), (a) unadjusted, (b) case-mix adjusted, and (c) excluding long-term sick; and according to individual (social grade) socioeconomic positions, (d) unadjusted, (e) case-mix adjusted, and (f) excluding long-term sick.

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 United Kingdom and in other high-income countries, interventions to improve early kidney care (the point where 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, and prescribing of beneficial new therapies such as sodium-glucose cotransporter-2 inhibitors) but adapted through systematic planning and evaluation to ensure that we are better able to recognize and meet those in greatest need, supported by 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 organizations, 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 health care 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 therefore be prepared 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 the existing literature from cohorts recruited in the United States reporting a relationship between household income and the development of chronic kidney disease (CKD) in adults in the third National Health and Nutrition Examination Survey (NHANES III),[31,33,67] between socioeconomic status and the development of CKD in the Atherosclerosis Risk in Communities (ARIC) study,[62] and between neighborhood area and the 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) study in Europe.[34,68] Our analysis adds to these recruited cohorts: by using a nonselective adult population, by combining both neighborhood and household measures, and by showing greater evidence of inequity at early versus later stages of disease. Further analyses from the Study of Heart and Renal Protection (SHARP) trial reported increased risk of mortality and vascular events in people with CKD without formal education[69] and increased risk of falling into poverty in people with advanced CKD.[32] Although 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] between childhood risk factors and adult CKD,[30,72] and between 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 health care provider did not recognize the kidney impairment in their blood results. This addresses some selection issues and imprecise measures in other studies. Even so, we recognize that this still relies on a blood test happening, which means that some of the challenges faced by people may still be underrepresented. Concerns of inequitable care based on race and ethnicity are substantial and sobering, particularly in studies from the United States.[74] We could not study this as the population identified with kidney disease comprised 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 recognize 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 onward. This means that we need to be cautious about the causal direction of socioeconomic circumstances affecting 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 recognize that comorbidity adjustment, although not central to the analysis, was based on hospitalization 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 health care 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 health care, monitoring, and support.

In conclusion, in a newly linked population health and social data set 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 neighborhood deprivation and adverse household socioeconomic position were complex. Both separately were associated with poorer kidney health outcomes, whereas 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, to obtain health care, and to live well.

DISCLOSURE

All the authors declared no competing interests.

DATA STATEMENT

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

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Supplementary material is available online at www.kidney-international.org.

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