



# Social Deprivation and Incident Diabetes-Related Foot Disease in Patients With Type 2 Diabetes: A Population-Based Cohort Study

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Jenny Riley,<sup>1</sup> Christina Antza,<sup>2,3</sup>  
Punith Kempegowda,<sup>2</sup>  
Anuradha Subramanian,<sup>1</sup>  
Joht Singh Chandan,<sup>1</sup> Krishna Gokhale,<sup>1</sup>  
Neil Thomas,<sup>1</sup> Christopher Sainsbury,<sup>1</sup>  
Abd A. Tahrani,<sup>2,3,4</sup> and  
Krishnarajah Nirantharakumar<sup>1</sup>

## OBJECTIVE

To investigate the relationship between social deprivation and incident diabetes-related foot disease (DFD) in newly diagnosed patients with type 2 diabetes.

## RESEARCH DESIGN AND METHODS

A population-based open retrospective cohort study using The Health Improvement Network (1 January 2005 to 31 December 2019) was conducted. Patients with type 2 diabetes free of DFD at baseline were stratified by Townsend deprivation index, and risk of developing DFD was calculated. DFD was defined as a composite of foot ulcer (FU), Charcot arthropathy, lower-limb amputation (LLA), peripheral neuropathy (PN), peripheral vascular disease (PVD), and gangrene.

## RESULTS

A total of 176,359 patients were eligible (56% men; mean age 62.9 [SD 13.1] years). After excluding 26,094 patients with DFD before/within 15 months of type 2 diabetes diagnosis, DFD incidentally developed in 12.1% of the study population over 3.27 years (interquartile range 1.41–5.96). Patients in the most deprived Townsend quintile had increased risk of DFD compared with those in the least deprived (adjusted hazard ratio [aHR] 1.22; 95% CI 1.16–1.29) after adjusting for sex, age at type 2 diabetes diagnosis, ethnicity, smoking, BMI, HbA<sub>1c</sub>, cardiovascular disease, hypertension, retinopathy, estimated glomerular filtration rate, insulin, glucose/lipid-lowering medication, and baseline foot risk. Patients in the most deprived Townsend quintile had higher risk of PN (aHR 1.18; 95% CI 1.11–1.25), FU (aHR 1.44; 95% CI 1.17–1.77), PVD (aHR 1.40; 95% CI 1.28–1.53), LLA (aHR 1.75; 95% CI 1.08–2.83), and gangrene (aHR 8.49; 95% CI 1.01–71.58) compared with those in the least.

## CONCLUSIONS

Social deprivation is an independent risk factor for the development of DFD, PN, FU, PVD, LLA, and gangrene in newly diagnosed patients with type 2 diabetes. Considering the high individual and economic burdens of DFD, strategies targeting patients in socially deprived areas are needed to reduce health inequalities.

Diabetes is a major public health challenge, affecting >400 million people worldwide (1). In the U.K., an estimated £14 billion is spent per year on treating diabetes, driven by the cost of treating diabetes-related complications (2).

The global prevalence of diabetes-related foot disease (DFD) is estimated to be 6.3%, and it is one of the most expensive complications of diabetes (3,4). Lifetime

<sup>1</sup>Institute of Applied Health Research, University of Birmingham, Birmingham, U.K.

<sup>2</sup>Institute of Metabolism and Systems Research, University of Birmingham, Birmingham, U.K.

<sup>3</sup>Department of Diabetes and Endocrinology, University Hospitals NHS Foundation Trust, Birmingham, U.K.

<sup>4</sup>Centre of Endocrinology, Diabetes and Metabolism, Birmingham Health Partners, Birmingham, U.K.

Corresponding author: Abd A. Tahrani, [abd.tahrani@nhs.net](mailto:abd.tahrani@nhs.net)

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A.A.T. and K.N. share equal authorship.

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incidence of diabetes-related foot ulceration (DFU) is 19–34%; lower-limb amputation (LLA) incidence rate in diabetes is 2.51 per 1,000 person-years, and prevalence of diabetes peripheral neuropathy (DPN) is 50% (5–8). DFU and LLA are associated with significant disability (9) and increased mortality (5-year mortality risk 70% after LLA and 50% after DFU) (10).

DPN and peripheral vascular disease (PVD) are major contributors to the development of DFD, DFU, and LLA (11). Current preventive strategies are focused on preventing PVD and DPN by improving glycemic control and cardiovascular (CV) risk factors and providing appropriate education and footwear to patients (12). These have resulted in reduction in risk of LLA (12), but DFD remains common, and therefore better understanding of the risk factors is needed.

Social deprivation is a potential contributor to risk of DFD because it is associated with obesity and CV risk and development of type 2 diabetes (13). Therefore, we hypothesized that social deprivation is a risk factor for DFD in patients with type 2 diabetes.

To examine our hypothesis, we conducted a large population-based cohort study using a U.K. nationally representative primary care database aimed at examining the relationship between social deprivation and incidence of DFD.

## RESEARCH DESIGN AND METHODS

### Study Design

A population-based open retrospective cohort study using routinely collected data from The Health Improvement Network (THIN) database between 1 January 2005 and 31 December 2019 was conducted.

### Data Source: THIN

THIN consists of anonymized primary care records taken from >800 U.K. general practices. The database is largely representative of the U.K. population in terms of demographics and morbidity prevalence (14). The data set consists of symptoms, examinations, and diagnoses, which are recorded using a hierarchical coding system called Read codes (15,16).

### Study Population and Inclusion and Exclusion Criteria in Exposed Cohort

All patients were recruited from practices that had been using the vision electronic

system for 1 year and had acceptable mortality reporting. Patients were eligible to join the exposed cohort if they had developed type 2 diabetes (based on Read codes) during follow-up (Supplementary File 1). Patients with a coded diagnosis of type 1 diabetes were excluded. Furthermore, patients whose age at diagnosis was <30 years with a record of insulin prescription and no prescription record of any oral diabetes medication in their medical history were excluded, because they were considered to have been potentially misclassified as having type 2 diabetes. Patients who already had one of the outcomes of interest at baseline and those who developed them between diagnosis date and index date (i.e., 15 months after type 2 diabetes diagnosis) were excluded from incident analysis. Latency period provided a 15-month window of opportunity for assessment of baseline foot risk and documentation of diabetes-related covariates.

The exposed cohort was subcategorized by Townsend deprivation score, which is the independent exposure variable in this study. Townsend score is a measure of material deprivation developed in 1988 from census tables (17). It includes unemployment, overcrowding, car ownership, and home ownership for small geographies, which are z-scored to produce an overall score. This is the deprivation marker included in the primary care record, derived from a patient's postcode. Townsend score is already recorded in THIN database as quintiles, with quintile 1 as the lowest (least deprived) and 5, the highest.

### Outcomes and Covariates

Primary outcome of the study was incident diagnosis of DFD (composite outcome of DFU, PVD, DPN, Charcot arthropathy, LLA, and gangrene).

Covariates included age at type 2 diabetes diagnosis, sex, ethnicity, BMI, smoking, glucose-lowering treatment, lipid-lowering medication, insulin treatment as proxy for diabetes disease severity, estimated glomerular filtration rate (eGFR), hemoglobin A<sub>1c</sub> (HbA<sub>1c</sub>), retinopathy, hypertension, CV disease, and baseline foot risk score. Baseline foot risk coded from the relevant Read codes was categorized as 1) low risk (normal sensation, palpable pulses), 2) increased/moderate risk (neuropathy or absent pulses), 3) high risk (neuropathy or

absent pulses plus deformity or skin changes in previous ulcer), 4) nonattendance of foot examination, or 5) missing foot risk data (18) (Supplementary File 1). Primary care practitioners insert foot risk scores as per their contractual agreement into the electronic system in the form of Read codes.

### Follow-up Period

Follow-up period began from the index date (15 months after type 2 diabetes diagnosis) until the patient exit date (earliest date of either the outcome of interest, patient transfer to another practice, final data collection date from general practice, or death).

### Ethical Approval

THIN data collection scheme received multicenter research ethics committee approval in 2003 (Birmingham, U.K.), and for this particular study, scientific review committee approval (reference number 18THIN090) was obtained in December 2018.

### Statistical Analysis

Continuous variables are presented as mean and SD or median and interquartile range (IQR) depending on their distribution. Binary and categorical variables are presented as frequencies and percentages.

Data cleaning and analysis were performed using Stata 16. Cox proportional hazards model was used to calculate crude and adjusted hazard ratios (aHRs) of the composite DFD and individual components of the composite outcome among patients in each Townsend deprivation quintile compared with those in quintile 1 (i.e., least deprived). Proportional hazards assumption was checked using log-log plots. At cohort entry, using a logistic regression model, we calculated the odds ratio (OR) of DFD diagnosis before or within 15 months of diabetes diagnosis among patients from each Townsend deprivation quintile compared with those in quintile 1.

All effect sizes (HRs and ORs) were calculated along with 95% CIs. A *P* value <0.05 was considered statistically significant.

## RESULTS

### Study Population Characteristics

Baseline characteristics of patients with a coded diagnosis of type 2 diabetes after exclusion of those considered as potentially misclassified are summarized

**Table 1—Baseline characteristics in total population and according to Townsend deprivation quintile**

	Quintile					All (n = 176,359)
	1 (n = 31,732)	2 (n = 30,655)	3 (n = 32,021)	4 (n = 29,984)	5 (n = 22,881)	Missing (n = 29,086)
Mean (SD) age, years	64.52 (12.26)	64.59 (12.62)	63.02 (13.12)	62.15 (13.60)	60.64 (13.58)	61.83 (13.30)
Age category, years						
<30	105 (0.33)	145 (0.47)	195 (0.61)	262 (0.87)	232 (1.01)	199 (0.68)
30–40	646 (2.04)	747 (2.44)	1,136 (3.55)	1,380 (4.60)	1,277 (5.58)	1,290 (4.44)
40–50	3,242 (10.22)	3,197 (10.43)	4,143 (12.94)	4,336 (14.46)	3,712 (16.22)	4,174 (14.35)
50–60	7,241 (22.82)	6,670 (21.76)	7,494 (23.40)	7,002 (23.35)	5,829 (25.48)	7,337 (25.23)
60–70	9,611 (30.29)	8,988 (29.32)	8,993 (28.08)	7,950 (26.51)	5,863 (25.62)	7,770 (26.71)
>70	10,887 (34.31)	10,908 (35.58)	10,060 (31.42)	9,054 (30.20)	5,968 (26.08)	8,316 (28.59)
Male sex	18,779 (59.18)	17,518 (57.15)	17,828 (55.68)	16,114 (53.74)	12,041 (52.62)	16,497 (56.72)
Ethnicity						
Caucasian	13,452 (42.39)	13,911 (45.38)	14,626 (45.68)	13,938 (46.48)	11,467 (50.12)	13,394 (46.05)
Afro-Caribbean	583 (1.84)	573 (1.87)	1,010 (3.15)	1,244 (4.15)	1,038 (4.54)	1,426 (4.90)
South Asian	159 (0.50)	168 (0.55)	357 (1.11)	499 (1.66)	687 (3.00)	653 (2.25)
Mixed race	143 (0.45)	126 (0.41)	196 (0.61)	200 (0.67)	234 (1.02)	372 (1.28)
Chinese/Middle Eastern/other	45 (0.14)	51 (0.17)	62 (0.19)	87 (0.29)	78 (0.34)	112 (0.39)
Missing	17,350 (54.68)	15,826 (51.63)	15,770 (49.25)	14,016 (46.74)	9,377 (40.98)	13,129 (45.14)
Smoking status						
Nonsmoker	16,917 (53.31)	15,410 (50.27)	14,909 (46.56)	12,920 (43.09)	9,153 (40.00)	14,052 (48.31)
Smoking discontinued	11,638 (36.68)	11,503 (37.52)	11,921 (37.23)	11,029 (36.78)	7,810 (34.13)	10,010 (34.42)
Smoker	3,122 (9.84)	3,710 (12.10)	5,146 (16.07)	6,005 (20.03)	5,888 (25.73)	5,006 (17.21)
Missing	55 (0.17)	32 (0.10)	45 (0.14)	30 (0.10)	30 (0.13)	18 (0.06)
Median (IQR) BMI, kg/m <sup>2</sup>	29.00 (26.00–33.00)	30.00 (26.00–34.00)	30.00 (27.00–35.00)	31.00 (27.00–35.00)	31.00 (27.00–36.00)	30.00 (27.00–35.00)
BMI category, kg/m <sup>2</sup>						
Underweight (<18.5)	145 (0.46)	164 (0.53)	159 (0.50)	116 (0.39)	128 (0.56)	142 (0.49)
Normal weight (18.5–25)	4,762 (15.01)	4,106 (13.39)	3,844 (12.00)	3,455 (11.52)	2,629 (11.49)	3,656 (12.57)
Overweight (25–30)	11,482 (36.18)	10,479 (34.18)	10,137 (31.66)	8,890 (29.65)	6,233 (27.24)	9,079 (31.21)
Obese (>30)	14,810 (46.67)	15,374 (50.15)	17,320 (54.09)	17,000 (56.70)	13,485 (58.94)	15,720 (54.05)
Missing	533 (1.68)	532 (1.74)	561 (1.75)	523 (1.74)	406 (1.77)	489 (1.68)
Mean (SD) HbA <sub>1c</sub> , mmol/mol	58.54 (21.73)	59.04 (22.17)	59.40 (22.28)	59.87 (22.61)	60.45 (23.16)	59.57 (22.44)
HbA <sub>1c</sub> recorded	30,459 (95.99)	29,502 (96.24)	30,800 (96.19)	28,621 (95.45)	21,913 (95.77)	27,930 (96.03)
HbA <sub>1c</sub> category, mmol/mol*						
≤47.5	10,781 (33.98)	10,191 (33.24)	10,365 (32.37)	9,352 (31.19)	7,138 (31.20)	9,498 (32.65)
47.5–58.5	10,168 (32.04)	9,937 (32.42)	10,294 (32.15)	9,538 (31.81)	7,038 (30.76)	9,166 (31.51)
58.5–69.4	3,014 (9.50)	2,943 (9.60)	3,232 (10.09)	3,131 (10.44)	2,383 (10.41)	2,936 (10.09)
>69.4	6,496 (20.47)	6,431 (20.98)	6,909 (21.58)	6,600 (22.01)	5,354 (23.40)	6,330 (21.76)
Missing	1,273 (4.01)	1,153 (3.76)	1,221 (3.81)	1,363 (4.55)	968 (4.23)	1,156 (3.97)
Mean (SD) eGFR, mL/min/1.73 m <sup>2</sup>	78.55 (18.74)	78.62 (19.46)	80.17 (19.90)	80.78 (20.36)	82.71 (20.83)	81.94 (19.98)
eGFR recorded	31,001 (97.70)	29,704 (96.90)	31,210 (97.47)	29,230 (97.49)	22,486 (98.27)	28,674 (98.58)

Continued on p. 734

Table 1—Continued

	Quintile						All (n = 176,359)
	1 (n = 31,732)	2 (n = 30,655)	3 (n = 32,021)	4 (n = 29,984)	5 (n = 22,881)	Missing (n = 29,086)	
eGFR category, mL/min/1.73 m <sup>2</sup>							
≥60	26,200 (82.57)	24,866 (81.12)	26,515 (82.81)	24,748 (82.54)	19,410 (84.83)	24,835 (85.38)	146,574 (83.11)
30–59	4,571 (14.41)	4,575 (14.92)	4,424 (13.82)	4,230 (14.11)	2,876 (12.57)	3,636 (12.50)	24,312 (13.79)
<30	230 (0.72)	263 (0.86)	271 (0.85)	252 (0.84)	200 (0.87)	203 (0.70)	1,419 (0.80)
Missing	731 (2.30)	951 (3.10)	811 (2.53)	754 (2.51)	395 (1.73)	412 (1.42)	4,054 (2.30)
CV disease	7,052 (22.22)	7,222 (23.56)	7,522 (23.49)	7,331 (24.45)	5,702 (24.92)	6,255 (21.51)	41,084 (23.30)
Hypertension	17,731 (55.88)	17,250 (56.27)	17,675 (55.20)	16,148 (53.86)	11,988 (52.39)	15,495 (53.27)	96,287 (54.60)
Retinopathy	905 (2.85)	949 (3.10)	1,038 (3.24)	995 (3.32)	773 (3.38)	942 (3.24)	5,602 (3.18)
Treatment							
Insulin	629 (1.98)	641 (2.09)	768 (2.40)	752 (2.51)	665 (2.91)	738 (2.54)	4,193 (2.38)
Lipid drugs	23,254 (73.28)	22,415 (73.12)	23,450 (73.23)	21,918 (73.10)	16,926 (73.97)	20,084 (69.05)	128,047 (72.61)
Other diabetes drugs	16,826 (53.03)	16,280 (53.11)	18,244 (56.98)	17,761 (59.23)	14,209 (62.10)	17,294 (59.46)	100,614 (57.05)
Foot risk							
High	391 (1.23)	485 (1.58)	495 (1.55)	513 (1.71)	454 (1.98)	369 (1.27)	2,707 (1.53)
Moderate	2,346 (7.39)	2,344 (7.65)	2,696 (8.42)	2,599 (8.67)	2,193 (9.58)	2,394 (8.23)	14,572 (8.26)
Low	12,985 (40.92)	13,044 (42.55)	13,568 (42.37)	12,699 (42.35)	9,322 (40.74)	14,605 (50.21)	76,223 (43.22)
Declined	126 (0.40)	128 (0.42)	171 (0.53)	176 (0.59)	208 (0.91)	213 (0.73)	1,022 (0.58)
Missing	15,884 (50.06)	14,654 (47.80)	15,091 (47.13)	13,997 (46.68)	10,704 (46.78)	11,505 (39.56)	81,835 (46.40)
DfD†	4,437 (13.98)	4,554 (14.86)	4,910 (15.33)	4,720 (15.74)	3,830 (16.74)	3,643 (12.52)	26,094 (14.80)

Data presented as n (%) unless otherwise indicated. \*≤47.5 mmol/mol = ≤6.5%, 47.5–58.5 mmol/mol = 6.5–7.5%, 58.5–69.4 mmol/mol = 7.5–8.5%, and >69.4 mmol/mol = >8.5%. †DfD refers to baseline; these patients were excluded from study.

**Table 2—Townsend deprivation quintiles and incidence of DFD as composite outcome**

Townsend quintile	Composite DFD, n (%) <sup>*</sup>	Median (IQR) follow-up, years	Incidence rate per 1,000 person-years (95% CI)	aHR (95% CI) <sup>†</sup>	P
1	3,267 (11.97)	3.33 (1.42–6.03)	29.77 (28.77–30.81)	Ref	
2	3,238 (12.41)	3.29 (1.42–5.96)	31.17 (30.11–32.26)	1.04 (0.99–1.09)	0.110
3	3,278 (12.09)	3.25 (1.43–5.95)	30.45 (29.42–31.51)	1.04 (0.99–1.09)	0.092
4	3,133 (12.40)	3.17 (1.38–5.81)	31.69 (30.60–32.82)	1.10 (1.04–1.15)	<0.001
5	2,557 (13.42)	3.15 (1.34–5.72)	34.86 (33.54–36.24)	1.22 (1.16–1.29)	<0.001
Missing	2,680 (10.53)	3.38 (1.45–6.21)	25.32 (24.38–26.30)	0.94 (0.90–0.99)	0.028

<sup>\*</sup>In case of multiple DFD events at follow-up, censoring occurred at first event. <sup>†</sup>Adjustment model included sex, age at type 2 diabetes diagnosis, ethnicity, smoking, BMI, HbA<sub>1c</sub>, CV disease, retinopathy, renal function analyzed as eGFR, insulin treatment, glucose-lowering medication, and baseline foot risk.

in Table 1, stratified by Townsend quintile. Of the 176,359 patients included in our study, 31,732 (18.0%), 30,655 (17.4%), 32,021 (18.2%), 29,984 (17.0%), and 22,881 (13.0%) patients stratified among Townsend quintiles 1–5, respectively; 29,086 (10.8%) patients had a missing record of Townsend deprivation quintile.

Men comprised 56.0% of the total cohort, and mean age at cohort entry was 62.9 (SD 13.1) years. Patients from the most deprived quintile were younger at study entry compared with those in the least deprived (mean 60.64 (SD 13.58) vs. 64.52 [SD 12.26] years). A majority of included patients were obese (53.1%) and ex- (36.2%) or nonsmokers (47.3%). Patients from the most deprived quintile were more likely to have obesity at baseline and more likely to be current smokers compared with those from the least deprived (obesity 58.94% vs. 46.7%; current smokers 25.7% vs. 9.8%). HbA<sub>1c</sub> was recorded for 96.0% of study participants, with mean HbA<sub>1c</sub> value of 59.43 (SD 22.4) mmol/mol. Patients from the most deprived quintile were more likely to have a record of HbA<sub>1c</sub> >69.4 mmol/mol at baseline compared with those from the least deprived (23.4% vs. 20.5%). Ethnic minority patients were more likely to be from the highest deprivation quintile compared with the lowest (8.9% vs. 2.9%). Nearly half of participants had hypertension (54.6%) and a quarter had CV disease (23.3%) at baseline.

Patients in the most deprived quintile had higher percentages of high foot risk score (2.0% vs. 1.2%), insulin treatment (2.9% vs. 2.0%), and end-stage kidney disease (0.9% vs. 0.7%) at baseline compared with those from the least deprived.

### Social Deprivation and Baseline Odds of DFD

A total of 26,094 (14.8%) patients had a recording of DFD before the index date (either before diabetes diagnosis or during 15-month latency between diagnosis and index dates). The greatest percentage of patients with preexisting DFD was in the most deprived quintile: quintile 1 (14.0%), 2 (14.9%), 3 (15.3%), 4 (15.7%), 5 (16.7%), and missing Townsend data (12.5%).

After adjustment of variables highlighted in the RESEARCH DESIGN AND METHODS section (except baseline foot risk score because of potential collinearity with baseline foot disease), all Townsend quintiles were associated with higher adjusted OR of having DFD at index date, when compared with those in the least deprived quintile (i.e., Townsend deprivation quintile 1). Results show increasing odds of DFD at baseline with increased deprivation score: quintile 2 (aOR 1.04; 95% CI 1.00–1.09;  $P = 0.064$ ), 3 (aOR 1.14; 95% CI 1.09–1.19;  $P < 0.001$ ), 4 (aOR 1.18; 95% CI 1.13–1.24;  $P < 0.001$ ), and 5 (aOR 1.34; 95% CI 1.28–1.41;  $P < 0.001$ ). There were slightly lower adjusted odds of DFD recorded at baseline among those with a missing recording of Townsend (aOR 0.95; 95% CI 0.91–1.00;  $P = 0.054$ ).

### Social Deprivation and Incident Risk of DFD

Patients with preexisting DFD at baseline (14.8%) were then excluded from incident analysis. Of the 150,265 patients followed up, 18,153 (12.1%) developed DFD during median follow-up of 3.27 (IQR 1.41–5.96) years. Incidence rate (per 1,000 person-years) of developing DFD increased with increasing deprivation: quintile 1 (29.8; 95% CI 28.8–30.8),

2 (31.2; 95% CI 30.1–32.3), 3 (30.5; 95% CI 29.4–31.5), 4 (31.7; 95% CI 30.6–32.8), and 5 (34.9; 95% CI 33.5–36.2). After adjustment, this translated into statistically significant increased risk of developing DFD in quintiles 4 (aHR 1.10; 95% CI 1.04–1.15) and 5 (aHR 1.22; 95% CI 1.16–1.29). Additional details are listed in Table 2.

Of types of DFD, the most common outcome during follow-up was DPN (8.9%). Incidence of individual components of composite DFD outcomes (DPN, DFU, PVD, LLA, Charcot arthropathy, and gangrene) in different quintiles of Townsend score is summarized in Table 3 and Supplementary File 2.

Most notably, patients in the most deprived Townsend quintile (5) went on to have statistically significant increased risk of developing DPN (aHR 1.18; 95% CI 1.11–1.25), DFU (aHR 1.44; 95% CI 1.17–1.77), PVD (aHR 1.40; 95% CI 1.28–1.53), LLA (aHR 1.75; 95% CI 1.08–2.83), and gangrene (aHR 8.49; 95% CI 1.01–71.58) compared with patients in the least deprived. Incidence of Charcot arthropathy was higher among those in the most deprived Townsend quintile, but the increase in risk was not statistically significant (aHR 1.65; 95% CI 0.78–3.49).

### Risk Factors of DFD From Fully Adjusted Model

Details on aHRs of exposure Townsend deprivation quintile and included covariates in the fully adjusted Cox regression model are presented in Table 4. In the final adjusted model for incident risk of DFD, the following covariates emerged as risk factors in addition to social deprivation: older age (aHR 1.03; 95% CI 1.03–1.04), male sex (aHR 0.86; 95%

**Table 3—Townsend deprivation quintiles and incidence of DPN, DFU, PVD, LLA, Charcot arthropathy, and gangrene**

Outcome by quintile	n (%)	Median (IQR) follow-up, years	Incidence rate per 1,000 person-years (95% CI)	aHR (95% CI)*	P
<b>DPN</b>					
1	2,483 (9.10)	3.47 (1.51–6.18)	21.98 (21.13–22.86)	Ref	
2	2,449 (9.38)	3.43 (1.51–6.15)	22.88 (21.99–23.81)	1.04 (0.98–1.10)	0.169
3	2,394 (8.83)	3.39 (1.52–6.15)	21.53 (20.68–22.41)	1.01 (0.96–1.07)	0.716
4	2,320 (9.18)	3.32 (1.47–6.02)	22.72 (21.82–23.67)	1.08 (1.02–1.15)	0.006
5	1,836 (9.64)	3.31 (1.43–5.99)	24.05 (22.98–25.18)	1.18 (1.11–1.25)	<0.001
Missing	1,963 (7.72)	3.52 (1.54–6.38)	18.05 (17.27–18.87)	0.92 (0.87–0.98)	0.009
<b>DFU</b>					
1	192 (0.70)	3.94 (1.79–6.67)	1.57 (1.36–1.80)	Ref	
2	210 (0.80)	3.90 (1.80–6.64)	1.81 (1.58–2.07)	1.13 (0.93–1.38)	0.221
3	209 (0.77)	3.82 (1.76–6.65)	1.74 (1.52–1.99)	1.11 (0.91–1.35)	0.288
4	220 (0.87)	3.73 (1.71–6.55)	1.98 (1.74–2.26)	1.28 (1.05–1.55)	0.014
5	186 (0.98)	3.75 (1.70–6.49)	2.23 (1.93–2.58)	1.44 (1.17–1.77)	<0.001
Missing	222 (0.87)	3.95 (1.74–6.96)	1.89 (1.66–2.16)	1.18 (0.97–1.43)	0.103
<b>PVD</b>					
1	1,045 (3.83)	3.75 (1.67–6.47)	8.81 (8.29–9.36)	Ref	
2	1,067 (4.09)	3.71 (1.66–6.45)	9.49 (8.94–10.08)	1.06 (0.97–1.15)	0.201
3	1,141 (4.21)	3.61 (1.65–6.41)	9.84 (9.28–10.42)	1.11 (1.02–1.21)	0.015
4	1,093 (4.33)	3.55 (1.60–6.31)	10.22 (9.63–10.84)	1.15 (1.05–1.25)	0.002
5	994 (5.22)	3.53 (1.58–6.23)	12.49 (11.74–13.29)	1.40 (1.28–1.53)	<0.001
Missing	845 (3.32)	3.79 (1.67–6.76)	7.39 (6.91–7.91)	0.92 (0.84–1.01)	0.083
<b>LLA</b>					
1	32 (0.12)	3.95 (1.80–6.69)	0.26 (0.18–0.37)	Ref	
2	31 (0.12)	3.92 (1.80–6.67)	0.27 (0.19–0.38)	1.02 (0.62–1.67)	0.952
3	47 (0.17)	3.84 (1.77–6.67)	0.39 (0.29–0.52)	1.54 (0.98–2.42)	0.060
4	44 (0.17)	3.76 (1.72–6.58)	0.40 (0.29–0.53)	1.58 (1.00–2.50)	0.052
5	37 (0.19)	3.78 (1.71–6.53)	0.44 (0.32–0.61)	1.75 (1.08–2.83)	0.023
Missing	34 (0.13)	3.97 (1.76–7.00)	0.29 (0.21–0.40)	1.12 (0.69–1.82)	0.658
<b>Charcot arthropathy</b>					
1	13 (0.05)	3.96 (1.80–6.70)	0.11 (0.06–0.18)	Ref	
2	11 (0.04)	3.92 (1.80–6.67)	0.09 (0.05–0.17)	0.90 (0.40–2.02)	0.807
3	11 (0.04)	3.85 (1.78–6.67)	0.09 (0.05–0.16)	0.84 (0.38–1.89)	0.679
4	12 (0.05)	3.76 (1.72–6.59)	0.11 (0.06–0.19)	0.99 (0.45–2.19)	0.983
5	16 (0.08)	3.78 (1.72–6.54)	0.19 (0.12–0.31)	1.65 (0.78–3.49)	0.191
Missing	6 (0.02)	3.97 (1.76–7.01)	0.05 (0.02–0.11)	0.43 (0.16–1.14)	0.090
<b>Gangrene</b>					
1	1 (0.00)	3.96 (1.80–6.70)	0.01 (0.00–0.06)	Ref	
2	5 (0.02)	3.92 (1.80–6.67)	0.04 (0.02–0.10)	5.01 (0.58–42.94)	0.142
3	4 (0.01)	3.85 (1.78–6.67)	0.03 (0.01–0.09)	3.99 (0.44–35.85)	0.216
4	9 (0.04)	3.76 (1.72–6.59)	0.08 (0.04–0.16)	9.82 (1.23–78.17)	0.031
5	6 (0.03)	3.78 (1.72–6.54)	0.07 (0.03–0.16)	8.49 (1.01–71.58)	0.049
Missing	5 (0.02)	3.97 (1.76–7.01)	0.04 (0.02–0.10)	5.35 (0.62–46.07)	0.127

\*Results adjusted for age at type 2 diabetes diagnosis, sex, ethnicity, smoking status, BMI, eGFR, retinopathy, hypertension, cardiovascular disease, HbA<sub>1c</sub>, insulin treatment, glucose-lowering medication, and lipid-lowering medication.

CI 0.84–0.89 [for women compared with men]), Caucasian ethnicity (aHR 0.78, 95% CI 0.62–0.97 for mixed race; aHR 0.84, 95% CI 0.59–1.19 for Chinese/Middle Eastern/other; aHR 0.63, 95% CI 0.53–0.74 for Black Afro-Caribbean; and aHR 0.71, 95% CI 0.64–0.79 for South Asian [compared with Caucasian ethnicity]), obesity (aHR 1.17; 95% CI 1.11–1.22), ex- and current smoker status (aHR 1.10, 95% CI 1.06–1.14, and aHR 1.33, 95% CI 1.27–1.39, respectively [compared with nonsmokers]), poor glycemic control (aHR 1.10, 95% CI 1.04–1.16 among those with HbA<sub>1c</sub> between 58.5 and 69.4 mmol/mol, and aHR

1.19, 95% CI 1.14–1.25 among those with HbA<sub>1c</sub> >69.4 mmol/mol [compared with those with HbA<sub>1c</sub> <47.5 mmol/mol]), lower eGFR (aHR 1.14, 95% CI 1.09–1.19 among those with eGFR between 30 and 60 mL/min/1.73 m<sup>2</sup> [compared with those with eGFR >60 mL/min/1.73 m<sup>2</sup>]), higher foot risk score or non-recording or decline of foot risk examination (aHR 1.61, 95% CI 1.51–1.73 among patients with moderate foot risk score; aHR 2.73, 95% CI 2.34–3.19 among patients with high foot risk score; aHR 1.51, 95% CI 1.23–1.85 among those who declined foot examination; and aHR

2.00, 95% CI 1.93–2.07 among those with missing foot risk score [compared with those with low foot risk score]), concurrent diagnosis of CV disease (aHR 1.23; 95% CI 1.19–1.28), hypertension (aHR 1.03; 95% CI 1.00–1.07), sight-threatening retinopathy (aHR 1.14; 95% CI 1.08–1.19), and prescription for glucose-lowering medication (aHR 1.13; 95% CI 1.09–1.16) and insulin treatment (aHR 1.36; 95% CI 1.24–1.50).

## CONCLUSIONS

We found that social deprivation was a risk factor for development of DFD, DPN, DFU, PVD, LLA, and gangrene in patients



**Table 4—Risk factors for DFD from fully adjusted model**

Covariate	aHR (95% CI)	P
Townsend quintile		
1 (lowest deprivation)	Ref	
2	1.04 (0.99–1.09)	0.110
3	1.04 (0.99–1.09)	0.092
4	1.10 (1.04–1.15)	<0.001
5 (highest deprivation)	1.22 (1.16–1.29)	<0.001
Missing	0.94 (0.90–0.99)	0.028
Age at diagnosis, years	1.03 (1.03–1.04)	<0.001
Female sex	0.86 (0.84–0.89)	<0.001
Ethnicity		
Caucasian	Ref	
Mixed race	0.78 (0.62–0.97)	0.024
Chinese/Middle Eastern/other	0.84 (0.59–1.19)	0.324
Black Afro-Caribbean	0.63 (0.53–0.74)	<0.001
South Asian	0.71 (0.64–0.79)	<0.001
Missing	0.89 (0.86–0.91)	<0.001
BMI category, kg/m <sup>2</sup>		
Underweight (<18.5)	1.13 (0.91–1.40)	0.276
Normal weight (18.5–25)	Ref	
Overweight (25–30)	1.02 (0.97–1.07)	0.426
Obese (>30)	1.17 (1.11–1.22)	<0.001
Missing	0.96 (0.85–1.09)	0.511
Smoking status		
Nonsmoker	Ref	
Smoking discontinued	1.10 (1.06–1.14)	<0.001
Smoker	1.33 (1.27–1.39)	<0.001
Missing	1.04 (0.74–1.47)	0.810
HbA <sub>1c</sub> category, mmol/mol*		
<47.50	Ref	
47.50–58.50	1.03 (0.99–1.06)	0.188
58.50–69.40	1.10 (1.04–1.16)	<0.001
≥69.40	1.19 (1.14–1.25)	<0.001
Missing	0.98 (0.91–1.05)	0.554
eGFR category, mL/min/1.73 m <sup>2</sup>		
>60	Ref	
30–59	1.14 (1.09–1.19)	<0.001
<30	1.11 (0.95–1.31)	0.187
Missing	1.00 (0.92–1.08)	0.997
Concurrent conditions		
CV disease	1.23 (1.19–1.28)	<0.001
Hypertension	1.03 (1.00–1.07)	0.032
Retinopathy	1.14 (1.08–1.19)	<0.001
Insulin	1.36 (1.24–1.50)	<0.001
Other diabetic drugs	1.13 (1.09–1.16)	<0.001
Lipid drugs	0.98 (0.94–1.02)	0.253
Baseline foot risk		
No recording	2.00 (1.93–2.07)	<0.001
Foot examination declined	1.51 (1.23–1.85)	<0.001
Low	Ref	
Medium	1.61 (1.51–1.73)	<0.001
High	2.73 (2.34–3.19)	<0.001

\*≤47.5 mmol/mol = ≤6.5%, 47.5–58.5 mmol/mol = 6.5–7.5%, 58.5–69.4 mmol/mol = 7.5–8.5%, and ≥69.4 mmol/mol = ≥8.5%.

newly diagnosed with type 2 diabetes. Findings remained significant despite adjustment for many important covariates including sex, age, ethnicity, smoking status, BMI, HbA<sub>1c</sub>, CV disease, hypertension, retinopathy, eGFR, insulin or other prescribed diabetes medication, lipid-

lowering medication, and foot risk score at baseline.

There are several plausible mechanisms that might explain the links between social deprivation and DFD observed in our study. Previous studies from the U.K. showed that the association between living

in more deprived neighborhoods and adverse health outcomes was related to poorer collective resources in these areas (19). Thus, socially deprived areas might have fewer resources to prevent, detect, and treat DFD risk factors. Another study in the U.K. showed the impact

of unhealthy lifestyle factors (e.g., sleep duration, high television viewing time, smoking, excessive alcohol, poor diet, and low physical activity) on health, CV disease, and mortality was disproportionately higher in socially more deprived areas (20). In addition, more deprived areas differ from less deprived areas in built environment, which can lead to differences in physical activity, availability of healthier food options, and smoking habits, all of which can result in worse DFD risk factors in areas of greater social deprivation (21,22). In addition, socially and economically deprived patients find self-management more challenging because of multiple barriers (23,24), which can increase risk of DFD because following appropriate preventive strategies is more difficult.

Other studies have also examined the relationship between DFD and social deprivation (25–28). Our results are consistent with other studies from the U.K. and add to their findings. Two U.K. studies, which included >10,000 participants each, found that deprivation was associated with either increased risk of DFU or mortality after DFU (26,29). However, these studies either were cross-sectional (25), included patients with both type 1 and 2 diabetes (25,26), focused on foot ulcer (27), or were based on regional data (28). Our study specifically looked at patients with newly diagnosed type 2 diabetes, used a database that covers multiple regions in the U.K., was a retrospective cohort study by design, and examined a wide range of DFD outcomes. Thus, our study adds novel insights to previously published literature.

Many of the studies that examined the relationship between social deprivation and DFD did not adjust for ethnicity. Adjusting for ethnicity is important, considering South Asians have been shown previously to have lower risk of DFU, LLA, and DPN compared with White Europeans with type 2 diabetes (30–32). Our findings are consistent with these studies indicating that non-White ethnicity is associated with lower DFD risk; however, we expand that finding, because the relationship between social deprivation and DFD was independent of ethnicity in our analysis.

Not all previous studies showed a relationship between DFD and social deprivation. One study from North-West

England did not show an association between socioeconomic status and new foot ulcers in adults with type 1 or 2 diabetes (27), but in this study, follow-up duration was shorter than that in our study (2 years), and it did not exclude patients with DFU at baseline. Three other studies from outside the U.K. found no association between socioeconomic factors and infection, amputation, or DFD, but these studies were small and potentially underpowered ( $n = 572$ ,  $n = 112$ , and  $n = 102$ , respectively) (33–35).

Our results are important because they identify a population at increased risk of developing DPN, DFD, DFU, LLA, and gangrene. By focusing on screening as a preventive strategy in a high-risk population, we could reduce health and economic burdens of DFD and type 2 diabetes and reduce health inequalities. Implementing preventive strategies and improving strategies to detect feet at risk should be addressed in deprived communities. Furthermore, better management through access to podiatrists, education, appropriate footwear, and CV disease risk factor management might address the higher DFD risk in patients from socially deprived areas (36).

Effect sizes reported in this study for association between social deprivation and DFD were modest. This reflects the multifactorial nature of DFD development, where multiple other DFD risk factors were also identified in our study with similar modest effect sizes, such as obesity, CV disease, smoking, and poor glycemic control. In addition, identifying socially deprived patients as a high-risk population for DFD is likely to be beneficial for a wider range of DFD risk factors, considering established links between DFD and obesity and CV disease (20).

Our findings show that having a high foot risk score (defined based on multiple clinical parameters) had the largest effect size in terms of predicting DFD. This is consistent with a previous study that showed using combined risk score/tests had better sensitivity than using individual tests in predicting development of DFD (37).

Results of the current study should be interpreted within the context of study limitations and strengths. One possible limitation is that use of routinely

collected primary care data may lack accuracy and completeness of recording. However, THIN has been shown to be representative of the U.K. population in terms of mortality and major chronic diseases (14,38,39). Another possible limitation is the possibility of delayed type 2 diabetes diagnosis in the deprived quintile, resulting in a more severe diabetes cohort among the deprived subgroups. However, a latency period of 15 months provides sufficient time to record for proxy covariates that indicate diabetes severity such as insulin prescription, HbA<sub>1c</sub> measurement, and concurrent macrovascular complications like retinopathy and nephropathy. We adjusted for these covariates in our analysis. Another limitation is the large proportion of missing ethnicity data. However, we used a missing ethnicity category in multivariable analysis to minimize the impact of missing data on this variable. Reassuringly, our analysis showed that South Asian and Black Afro-Caribbean patients had lower risk of incident DFD compared with White Caucasians, which is consistent with previous studies (30,32,40). This is the largest population-based study representative of the U.K. population to date examining the impact of deprivation on DFD and reporting outcomes other than DFU and LLA. The large sample size also allowed us to adjust for many biologically important covariates.

In conclusion, deprivation is a risk factor of DFD, DPN, DFU, PVD, LLA, and gangrene in patients newly diagnosed with type 2 diabetes. Screening and preventive strategies targeting this high-risk population could reduce economic and health burdens of type 2 diabetes and reduce inequalities.

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**Author Contributions.** J.R. organized and conducted the study. C.A. interpreted the results, proposed the structure of the paper, and formulated the paper. P.K., A.S., and J.S.C. interpreted the results and performed statistical analysis. K.G., N.T., and C.S. critically appraised the paper and made final suggestions. A.A.T. and K.N. proposed the idea, critically appraised the paper, and made final suggestions. All authors reviewed and revised the manuscript and agreed to submission of the final manuscript. A.A.T. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.



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