Association between social deprivation and incidence of first seizures and epilepsy: A prospective population-based cohort

Eimer M. Maloney1,2,3 | Paul Corcoran3 | Daniel J. Costello1,2,4 | Éilis J. O’Reilly3,5,6

1Epilepsy Service, Department of Neurology, Cork University Hospital, Cork, Ireland
2School of Medicine, University College Cork, Cork, Ireland
3School of Public Health, University College Cork, Cork, Ireland
4FutureNeuro SFI Research Centre for Chronic and Rare Neurological Diseases, Hosted by Royal College of Surgeons in Ireland University of Medicine and Health Sciences, Dublin, Ireland
5Department of Nutrition, Harvard T. H. Chan School of Public Health, Boston, Massachusetts, USA
6Environmental Research Institute, University College Cork, Cork, Ireland

Correspondence
Eimer Maloney, Department of Neurology, Cork University Hospital, Cork, Ireland. Email: eimer.m.maloney@gmail.com

Abstract

Objective: Epidemiologic studies have investigated whether social deprivation is associated with a higher incidence of epilepsy, and results are conflicting, especially in children. The mechanisms underlying a potential association are unclear. This study examines whether there is an association between social deprivation and the incidence of first seizures (unprovoked and provoked) and new diagnosis of epilepsy by comparing incidence across an area-level measure of deprivation in a population-based cohort.

Methods: Multiple methods of case identification followed by individual case validation and classification were carried out in a defined geographical area (population 542,868) to identify all incident cases of first provoked and first unprovoked seizures and new diagnosis of epilepsy presenting during the calendar year 2017. An area-level relative deprivation index, based on 10 indicators from census data, was assigned to each patient according to registered address and categorized into quintiles from most to least deprived.

Results: The annual incidence of first unprovoked seizures ($n=372$), first provoked seizures ($n=189$), and new diagnosis of epilepsy ($n=336$) was highest in the most deprived areas compared to the least deprived areas (incidence ratios of 1.79 [95% confidence interval (CI) = 1.26–2.52], 1.55 [95% CI = 1.04–2.32], and 1.83 [95% CI = 1.28–2.62], respectively). This finding was evident in both adults and children and in those with structural and unknown etiologies of epilepsy.

Significance: The incidence of first seizures and new diagnosis of epilepsy is associated with more social deprivation. The reason for this higher incidence is likely multifactorial.

Keywords

epilepsy, incidence, seizures, social deprivation

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

© 2022 The Authors. Epilepsia published by Wiley Periodicals LLC on behalf of International League Against Epilepsy.
1 INTRODUCTION

Some studies have shown a correlation between social deprivation and prevalence of epilepsy.\(^1\)\(^-\)\(^3\) A higher prevalence of epilepsy among residents living in socially deprived areas may be due to "social drift," whereby factors associated with a diagnosis of epilepsy, for example, decreased employability, lead to a downward drift of the socioeconomic status of an individual.\(^4\) An alternative explanation is "social causation," whereby factors associated with living in an area of social deprivation put an individual at increased risk of developing epilepsy.

A strong correlation between the incidence of epilepsy and social deprivation has been reported in Wales\(^5\) and England.\(^5\) Using census-based measures of social deprivation, these studies reported at least twice the annual incidence of epilepsy in the most deprived geographically defined areas compared to the least deprived areas. Furthermore, a community-based study in New York reported a higher incidence of unprovoked seizures in low-income compared to high-income households.\(^6\) In contrast, a 1990 case-referent study from Sweden investigating the incidence of unprovoked seizures in adults found no difference in individual markers of sociodemographic status between cases and controls.\(^7\)

Results from studies investigating the incidence of epilepsy in children in socially deprived areas have also been conflicting. Using an area-level measure of deprivation, a study in England found no difference in the incidence of epilepsy across four quartiles of social deprivation in children aged 29 days to 14 years.\(^8\) In contrast, a Swedish study reported 1.15 times increased odds of registration for childhood and adolescent epilepsy in those living in high-deprivation neighborhoods compared to low-deprivation neighborhoods.\(^9\) Finally, a case–control study from Iceland\(^10\) found that low socioeconomic status, measured by low individual-level educational attainment or lack of home ownership, increased the risk of incident epilepsy in adults. However, no markers of socioeconomic status were associated with incident epilepsy in children.

To investigate further the magnitude and direction of the association with socioeconomic status, we sought to determine whether the incidence of provoked and unprovoked first seizures and of new diagnosis of epilepsy differed between areas of relatively high social deprivation compared to areas of relatively low social deprivation in our well-defined whole population cohort of children and adults.\(^11\) Furthermore, we sought to investigate whether certain etiologic categories of epilepsy are associated with social deprivation.

Key Points

- Children and adults in the most socially deprived communities have an excess burden of seizure disorders
- Social causation, rather than social drift, may be the primary mechanism for increased prevalence in areas of relative social deprivation
- The etiology of this association is likely multifactorial

2 MATERIALS AND METHODS

This study was carried out in the geographically defined area of Cork city and county, Ireland (estimated population 542,686 adults and children,\(^12\) geographic area approximately 7500 km\(^2\)). The area contains one large urban development encompassing approximately one quarter of the total population (125,657 persons). The remaining population lives in smaller towns, villages, or rural dwellings. The Irish health care system consists of both public and private hospitals. Patients with seizures either self-present to the emergency department or are referred to the emergency department or neurology outpatient department by their general practitioner.

2.1 Case ascertainment

A detailed description of the protocol applied to capture the case population has been previously published.\(^13\) In brief, multiple overlapping prospective and retrospective sources of case ascertainment were applied to the geographically defined area to capture all potential first seizures and new diagnosis of epilepsy during the calendar year 2017. Briefly, prospective capture methods included daily review of emergency department triage and radiology ordering databases, and liaison with inpatient medical teams and clinical nurse specialists in departments with a high likelihood of encountering seizures and epilepsy (specifically, neurology, neurosurgery, oncology, geriatrics, and pediatrics). Retrospective methods included review of electroencephalographic (EEG) databases, review of case presentations at the single Rapid Access Seizure Clinic within the catchment area, liaison with hospital consultants in the aforementioned inpatient and outpatient specialties, and postal survey of primary care and residential and nursing home settings within the catchment area. Review of case records extended to March 31, 2018 to capture and complete the classification of patients who first presented in 2017. By restricting our count to
first presentation during 2017, we avoid over- or under-ascertainment in the 2017 calendar year, and the number classified will estimate the true incidence of each clinical subcategory.

2.2 Inclusion criteria and case classification

Epileptic seizures were defined as a transient occurrence of signs and/or symptoms due to abnormal excessive or synchronous neuronal activity in the brain. Epilepsy was defined according to the International League Against Epilepsy (ILAE) operational definition: (1) at least two unprovoked seizures occurring >24 h apart, (2) one unprovoked seizure and probability of further seizures of approximately 60% or greater over the next 10 years, or (3) diagnosis of an epilepsy syndrome. A person with a single unprovoked seizure was estimated to have an approximately 60% or greater risk of recurrence if one or more of the following risk factors were identified: persons with a structural or remote symptomatic etiology and/or epileptiform abnormality on EEG, and adults with a significant structural brain imaging abnormality, neurodegenerative dementia, or extensive small vessel disease with juxta-cortical lesions. Patients with mild-to-moderate small vessel disease without juxtacortical involvement, other nonspecific findings, or normal investigations were classified as having single unprovoked seizures. Individuals who had a first seizure prior to 2017 (and were not diagnosed with epilepsy at that time) and then a second seizure in 2017 were included as “new diagnosis of epilepsy.” Individuals who had a single seizure in 2017 and did not have a 60% or greater risk of recurrence, or who had a recurrence after 2017, were included as “first seizure” only.

First seizures meeting the ILAE criteria for provoked seizures were identified as a specific subcohort, and were separated from first unprovoked seizures and epilepsy during analysis. In accordance with the ILAE epidemiologic guidelines, neonatal seizures and febrile seizures were excluded.

Review of documented medical history, EEG findings, and imaging was conducted by the study team (D.J.C. and E.M.M.) for patients with an address in the geographical area. In accordance with the ILAE epidemiologic guidelines, the probability that an event was a seizure was defined as definite, probable, or possible, based on the evidence available; see previously published methodology for detailed discussion. Only those meeting criteria for a definite or probable case were included in further analysis of seizures and epilepsy.

Patients with inadequate or unclear documentation were classified as indeterminate and were not included in further analysis.

2.3 Epilepsy risk factors and etiology

Based on review of the medical notes, the presence or absence of risk factors associated with seizures was noted. Specifically, a history of febrile seizures, central nervous system infection (meningitis or encephalitis), developmental delay, cerebrovascular disease (hemorrhagic, ischemic, large vessel, or small vessel), head injury (history of loss of consciousness following head injury or requiring inpatient observation or neurosurgical intervention), illicit drug use, alcohol abuse (>14 units per week), or psychiatric disease or family history of epilepsy (first degree relative with seizures or epilepsy) was noted. As this was based on retrospective chart review, the presence of such risk factors was often undocumented, and in these cases was coded as “unknown.” For all definite and probable cases of epilepsy, the etiology was classified according to the 2017 ILAE classification system as structural, genetic, immune, infectious, metabolic, or unknown.

2.4 Measure of socioeconomic status

Electoral divisions are legally defined administrative areas in Ireland. There are 398 electoral divisions within the geographic area studied. The 2016 Pobal HP Deprivation Index uses data from the 2016 Census of Population to calculate a Relative Deprivation Index (RDI) for each electoral division. The RDI is calculated by a factor analytical approach combining 10 indicators: percentage change in population over the previous 5 years, percentage change in population <15 or >64 years of age, percentage of population with primary school education only, percentage of population with third-level education, percentage of single parent households, mean number of persons per room, percentage of households headed by professionals, percentage of households headed by semiskilled or unskilled manual workers, and male and female unemployment rates. For each census year, the RDI in Ireland has a mean Deprivation Index of zero and an SD of 10. A higher RDI represents relatively less deprivation.

Each electoral division within the defined geographic area was ranked according to its RDI from most deprived to least deprived and categorized as quintiles. Quintile 1 refers to the relatively most deprived one fifth of the whole.
population and Quintile 5 to the relatively least deprived one fifth.

Each case included in the study was assigned an electoral division based on their registered address, and thereafter to the corresponding quintile of RDI. Subjects whose registered address was in a nursing home or residential care setting \((n = 18, 2\% \text{ of included cases},)\) convent \((n = 5, <1\%),\) or prison \((n = 2, <1\%)\) or who were homeless \((n = 5, <1\%)\) were not assigned an electoral division and were not included in the sociodemographic analysis.

### 2.5 Statistical analysis

Annual incidence of first unprovoked seizures, first provoked seizures, and new diagnosis of epilepsy in each quintile was calculated by dividing the number of people with a new diagnosis during the calendar year 2017 by the number of people living in the geographical area in that quintile and expressing it per 100,000 population. Ideally, people who already had a diagnosis of seizure or epilepsy prior to 2017 would be subtracted from the population of the geographic area when calculating incidence. However, the exact prevalence of seizures and epilepsy in the geographic area is unknown. Previous studies suggest that 10 per 1000 population of Ireland already have a diagnosis of epilepsy between the five quintiles, where data were available.

IRs of those with a new diagnosis of epilepsy with a structural, genetic, or unknown etiology were investigated between quintiles. Finally, we investigated whether there was a difference in the occurrence of specific risk factors for epilepsy between the five quintiles, where data were available.

---

### 2.6 Standard protocol approvals

The study protocol was approved by the University College Cork Clinical Ethics Research Committee. Following ascertainment, the data were anonymized prior to analysis and storage.

### 2.7 Role of the funding source

This study received no specific funding from any government, institution, or industry.

### 3 RESULTS

We identified 1264 potential cases with first presentation in 2017 for inclusion. Crude annual incidence of all definite and probable cases of first unprovoked seizures \((n = 372, 69 \text{ per 100,000}),\) first provoked seizure \((n = 189, 35 \text{ per 100,000}),\) and new diagnosis of epilepsy \((n = 336, 62 \text{ per 100,000})\) demonstrated a bimodal age-specific incidence. The male to female incidence ratio was 1.38 (95% CI = 1.13–1.70), 1.95 (95% CI = 1.44–2.63), and 1.34 (95% CI = 1.08–1.67), respectively.

### 3.1 Sociodemographic analysis

Table 1 shows the mean RDI for the geographic region overall (3.6) and for individuals with first unprovoked seizures (1.8), first provoked seizures (3.4), and new diagnosis of epilepsy (1.3).

Incidence was higher for each diagnostic category in the most deprived quintile compared to the least deprived quintile, ranging from 55% to 83% (see Table 2 and Figure 1). Adjustment for sex and age group attenuated results in the diagnostic categories of provoked seizures. Analysis of trend demonstrated that a one-unit increase in RDI is associated with an approximate 4% increase in first unprovoked seizures (95% CI = 2%–6%) and new diagnosis of epilepsy (95% CI = 2%–6%).

When age was dichotomized to separate children (aged 28 days to 14 years) from adults (aged ≥15 years), incidence remained highest in the most deprived compared to the least deprived quintile in adults and was almost twofold higher in children with first unprovoked seizures and new diagnosis of epilepsy (see Table 3).

When adults were divided into those aged 15–64 years and those aged ≥65 years, a higher incidence of first unprovoked and provoked seizures, and of new diagnosis of epilepsy, was present in the most deprived compared to the least deprived quintile for ages 15–64 years, but not in those aged ≥65 years (see Table S1).
When those with a new diagnosis of epilepsy were subdivided into those with a structural ($n = 175$), genetic ($n = 39$), or unknown etiology ($n = 101$), the incidence of epilepsy remained highest in the most deprived compared to the least deprived quintile (see Table 4). The number of cases with a genetic etiology was small, and results were not statistically significant in this group.
**TABLE 2** Annual incidence of first unprovoked seizures, first provoked seizures, and new diagnosis of epilepsy per 100,000 population in the most deprived electoral divisions compared to the least deprived electoral divisions

| Quintile | Study population, n | First unprovoked seizures | First provoked seizures | New diagnosis of epilepsy |
|----------|---------------------|---------------------------|-------------------------|--------------------------|
|          |                     | Incidence (95% CI)        | IR (95% CI)             | Adj IR (95% CI)          |
|          |                     | n                         | IR (95% CI)             | Adj IR (95% CI)          |
|          |                     | n                         | IR (95% CI)             | Adj IR (95% CI)          |
|          |                     | n                         | IR (95% CI)             | Adj IR (95% CI)          |
| 1        | 108 753             | 90                        | 82.8 (66.9–101.2)       | 85.1 (43.3–71.6)         | 85.1 (62.8–96.2) |
|          |                     |                           | IR = 1.79 (1.26–2.52), p < .001 | IR = 1.55 (1.04–2.32), p = .03 | IR = 1.83 (1.28–2.62), p < .001 |
|          |                     |                           | Adj IR = 1.63 (1.51–2.30), p = .006 | Adj IR = 1.42 (0.95–2.12), p = .08 | Adj IR = 1.66 (1.16–2.38), p = .006 |
| 2        | 108 396             | 91                        | 83.9 (68.0–102.6)       | 23.2 (13.8–31.3)         | 80.3 (64.7–98.5) |
|          |                     |                           | IR = 1.81 (1.27–2.56), p < .001 | IR = .59 (.39–.98), p = .04 | IR = 1.88 (1.32–2.69), p < .001 |
|          |                     |                           | Adj IR = 1.63 (1.15–2.31), p = .006 | Adj IR = .53 (.31–.90), p = .02 | Adj IR = 1.69 (1.18–2.43), p = .004 |
| 3        | 108 604             | 62                        | 57.1 (44.2–72.7)        | 28.5 (19.7–40.0)         | 84.2 (32.9–58.1) |
|          |                     |                           | IR = 1.23 (.85–1.79), p = .27 | IR = .79 (.49–1.27), p = .33 | IR = 1.03 (.69–1.55), p = .88 |
|          |                     |                           | Adj IR = 1.16 (.79–1.68), p = .45 | Adj IR = .75 (.47–1.21), p = .24 | Adj IR = .96 (.64–1.45), p = .86 |
| 4        | 109 171             | 65                        | 59.5 (46.3–75.4)        | 23.8 (15.9–34.4)         | 55.0 (42.3–70.2) |
|          |                     |                           | IR = 1.28 (.89–1.86), p = .18 | IR = .66 (.40–1.08), p = .10 | IR = 1.29 (.88–1.89), p = .19 |
|          |                     |                           | Adj IR = 1.24 (.86–1.79), p = .28 | Adj IR = .66 (.40–1.08), p = .10 | Adj IR = 1.24 (.84–1.82), p = .28 |
| 5 [least deprived] | 107 944             | 50                        | 46.3 (34.8–60.6)        | 36.1 (26.1–48.9)         | 42.6 (31.6–56.3) |
|          |                     |                           | Reference               | Reference                | Reference            |

*p for trend* = .0001

Note: Trend was calculated by logistic regression of median Relative Deprivation Index for cases and non-cases in each quintile.

Abbreviations: Adj IR, Mantel–Haenszel adjusted IR for sex and age group; CI, confidence interval; IR, incidence ratio.
Whether there was a history of febrile seizure was documented in 223 (68%) of individuals with a new diagnosis of epilepsy. Among these, 19% (n = 11) of the cases who lived in the most deprived quintile had a positive history of febrile seizures compared to 3% (n = 1) in the least deprived (see Table 5).

Family history was documented in 235 (72%) cases of new diagnosis of epilepsy, and of these, 50 (21%) reported a positive family history. There was no clear association across quintiles of deprivation (13% in the least deprived compared to 19%–24% in the remainder). To examine whether the association between deprivation and new diagnosis of epilepsy differed by family history, we grouped cases into those with a positive family history (n = 50) and those without family history or with undocumented family history (n = 276). The IR comparing most to least deprived remained elevated in those without family history or with undocumented family history (IR = 1.68, 95% CI = 1.15–2.46).

For most risk factors, the proportion of missing responses did not correlate with deprivation quintiles, with the exception of a history of drug or alcohol abuse, in which the highest proportion of cases with an unknown or undocumented history was in the least deprived quintile (n = 10, 22%).

**3.2 Epilepsy risk factors**

**DISCUSSION**

We found that individuals living in the most deprived quintile of the defined geographical area studied are 55%–83% more likely to be diagnosed with a first unprovoked seizure, first provoked seizure, or new onset epilepsy than those living in the least deprived quintile. The higher incidence of new diagnosis of epilepsy and first unprovoked seizures in deprived areas is evident in both children and adults. Finally, we report a higher incidence of both structural and unknown etiologies of epilepsy in areas of relatively high sociodemographic deprivation.

Similar to our results, higher incidence of unprovoked seizures and epilepsy in areas of relative socioeconomic deprivation has been reported in adults in England, Wales, Iceland, and northern Manhattan. Although the measure used in each study to determine socioeconomic status differed, concordance of results supports the conclusions.

Establishing the mechanism of the association between seizures, epilepsy, and socioeconomic deprivation is important to identify potentially modifiable risk factors. One possible explanation is increased occurrence of risk factors for development of epilepsy, such as traumatic brain injury, in areas of relatively high deprivation. However, we found a higher incidence of both structural and unknown etiologies of epilepsy in areas of deprivation. Environmental exposures are also worth considering. Air pollution has been found to be increased in areas of higher social deprivation. A small number of studies have reported a positive association between air pollution exposure and hospital visits for seizures. As a potentially modifiable risk factor that varies across areas of relatively high and low socioeconomic deprivation, the effect of air pollution on seizures and epilepsy deserves further study.
The number of cases in our study with a genetic etiology was small, and although incidence was highest in the most deprived areas, risk ratios in this subgroup were not statistically significant. In contrast, subgroup analysis of adult cases in Iceland found that low socioeconomic status, as indicated by educational attainment of the main wage earner and lack of home ownership, was significant only in the idiopathic/cryptogenic etiology subgroup and not in those with a remote symptomatic or progressive symptomatic etiology. Case numbers in the latter two groups were small. We applied the updated ILAE classification systems for seizures and epilepsy to our cohort. Application of these classification systems may have resulted in more accurate classification, revealing a true gradient.

In our study, 21% (n = 50) of cases of new diagnosis of epilepsy for whom it was recorded reported a positive family history. The proportion with a positive family history was lowest among those in the least deprived quintile (13%, n = 4), which may be consistent with the hypothesis of social drift. However, family history alone does not fully explain the difference in incidence, as the trend across quintiles was still evident after adjusting for family history. Our data on risk factors are incomplete, and we made an assumption that family history was negative in cases with an undocumented family history; therefore, it is difficult to draw firm conclusions from this aspect of our results. For most risk factors, the proportion of those without a documented history was similar across quintiles. No evidence of social drift was found in Iceland by comparing the socioeconomic status of persons with epilepsy to controls whose parents had epilepsy. In Wales, no evidence of social drift was found by following a cohort of patients with incident epilepsy for 10 years. Taken together, studies to date therefore suggest that social causation, rather than social drift, is the dominant factor contributing to the higher prevalence of epilepsy.

### TABLE 3 Annual incidence of first unprovoked seizures and new diagnosis of epilepsy per 100 000 population in those aged 28 days to 14 years of age and in those 15 years of age and older in the most deprived electoral divisions compared to the least deprived electoral divisions

| Quintile       | Study population, n | First unprovoked seizure | New diagnosis of epilepsy |
|----------------|---------------------|--------------------------|---------------------------|
|                | n                   | Incidence (95% CI)       | n                         |
| Persons 28 days–14 years old |                     |                          |                           |
| 1 [most deprived] | 20 341              | 20                       | 98.3 (61.8–149.1)         | 21 | 103.2 (65.6–155.1) |
|                 |                     | IR = 1.91 (.91–3.98), p = .08 | IR = 2.20 (1.04–4.68), p = .03 |
| 2               | 22 862              | 19                       | 83.1 (51.5–127.3)         | 14 | 61.2 (33.9–100.3) |
|                 |                     | IR = 1.61 (.77–3.89), p = .20 | IR = 1.31 (58–2.94), p = .52 |
| 3               | 24 233              | 19                       | 78.4 (48.6–120.15)        | 15 | 61.9 (36.0–99.8) |
|                 |                     | IR = 1.52 (.72–3.20), p = .26 | IR = 1.32 (.59–2.94), p = .49 |
| 4               | 24 761              | 20                       | 80.8 (50.7–122.5)         | 18 | 72.7 (44.4–112.6) |
|                 |                     | IR = 1.57 (.75–3.27), p = .23 | IR = 1.55 (.72–3.36), p = .26 |
| 5 [least deprived] | 21 334              | 11                       | 51.6 (27.1–89.6)          | 10 | 46.9 (23.8–83.5) |
|                 |                     | Reference                 | Reference                 |
| p for trend     |                     | p = .13                   | p = .07                   |

| Persons ≥ 15 years old | Study population, n | First unprovoked seizure | New diagnosis of epilepsy |
|------------------------|---------------------|--------------------------|---------------------------|
| 1 [most deprived]     | 88 412              | 70                       | 79.2 (62.2–99.4)          | 64 | 72.4 (56.2–91.8) |
|                       |                     | IR = 1.76 (1.19–2.60), p = .004 | IR = 1.74 (1.16–2.62), p = .007 |
| 2                     | 85 534              | 72                       | 84.2 (66.4–105.4)         | 73 | 85.3 (67.4–106.7) |
|                       |                     | IR = 1.87 (1.27–2.76), p = .001 | IR = 2.05 (1.38–3.06), p < .001 |
| 3                     | 84 371              | 43                       | 51.0 (37.4–68.0)          | 33 | 39.1 (27.4–54.3) |
|                       |                     | IR = 1.13 (.74–1.75), p = .57 | IR = .94 (.59–1.51), p = .80 |
| 4                     | 84 410              | 45                       | 53.3 (39.4–70.7)          | 42 | 49.8 (36.3–66.6) |
|                       |                     | IR = 1.18 (.77–1.82), p = .44 | IR = 1.20 (.77–1.87), p = .43 |
| 5 [least deprived]   | 86 610              | 39                       | 45 (32.5–60.9)            | 36 | 41.6 (29.6–56.9) |
|                       |                     | Reference                 | Reference                 |
| p for trend           |                     | p = .0003                 | p = .0002                 |

Note: Trend was calculated by logistic regression of median Relative Deprivation Index for cases and noncases in each quintile. Abbreviations: CI, confidence interval; IR, incidence ratio.
in areas of social deprivation. However, investigation of multigenerational clustering of genes that lower seizure threshold would require prolonged follow-up, multigenerational family history, and detailed genetic analysis of participants and would be difficult to perform at a population level. Furthermore, genetic factors influencing development of seizures and epilepsy in many cases remain poorly understood. Therefore, it is difficult to entirely rule out social drift as a potential contributing factor.

Similar to studies in Sweden,9 England,5 and Wales,4 we found the annual incidence of epilepsy in children was higher in the most deprived areas compared to the least deprived areas. The influence of a genetic etiology of epilepsy may be more relevant in younger persons than in adults, in whom focal epilepsy becomes more common. A genetic predisposition may be suggested by a history of febrile seizures, which was more common in the most deprived population quintiles compared to the least deprived quintiles. However, as our data were obtained from retrospective chart review, a proportion of cases in each quintile had unknown or undocumented risk factors.

The socioeconomic association was not seen in those aged ≥65 years. This may indicate that after a certain age, seizure risk is no longer influenced by socioeconomic factors. Alternatively, persons in less deprived areas may “delay” their risk to later in their lifetime, rather than “eliminate” it.

Analysis of trend demonstrated that a one-unit increase in RDI is associated with an approximate 4% increase in first unprovoked seizures, first provoked seizures, and new diagnosis of epilepsy. This trend was most evident when the 15–64-year-old subgroup was analyzed. Although the trend is not perfectly linear, taken together, our results suggest that the association between socioeconomic deprivation and seizures may be multifactorial.

To our knowledge, no previous study has reported the incidence of provoked seizures with regard to socioeconomic status. Increased incidence of provoked seizures in areas of higher deprivation could be related to higher prevalence of excessive alcohol intake and binge drinking.34,35 Similarly, risk factors for other causes of provoked seizures, such as cerebrovascular accidents,36 are more prevalent in areas of deprivation. Provoked seizures are associated with significant morbidity and mortality,37 and addressing risk factors for their development should be part of health policy.

A major strength of our study is the use of the 2016 Pobal HP Deprivation Index,26 which provides a multidomain, multivariable RDI as a continuous variable based on registered address that has been used to investigate the effect of socioeconomic status on survival in renal dialysis patients38 and renal transplant patients.39 Area-level measures similar to the RDI have been reported when investigating the association between epilepsy and socioeconomic deprivation in

### Table 4

| Quintile | Study population, n | Structural Incidence (95% CI) | Genetic Incidence (95% CI) | Unknown Incidence (95% CI) |
|----------|---------------------|-------------------------------|---------------------------|--------------------------|
| 1 [most deprived] | 108 753 | 47 43.2 (32.1–57.0), IR = 1.73 (1.08–2.78), p = .02 | 10 9.2 (4.7–16.4), IR = 1.98 (1.08–5.81), p = .20 | 26 23.9 (16.0–34.5), IR = 2.15 (1.08–4.26), p = .02 |
| 2 | 108 396 | 44 40.6 (29.9–54), IR = 1.62 (1.00–2.62), p = .04 | 11 10.1 (5.3–17.6), IR = 2.19 (0.76–3.60), p = .14 | 27 24.9 (16.8–35.7), IR = 2.24 (1.13–4.42), p = .02 |
| 3 | 108 604 | 26 23.9 (16–34.6), IR = .96 (.55–1.64), p = .87 | 6 5.5 (2.2–11.5), IR = 1.19 (.36–3.90), p = .77 | 16 14.7 (8.7–23.4), IR = 1.32 (.63–2.80), p = .46 |
| 4 | 109 171 | 31 28.4 (19.6–39.8), IR = 1.13 (.68–1.90), p = .63 | 7 6.4 (2.8–12.7), IR = 1.38 (.44–4.36), p = .58 | 20 18.3 (11.5–27.8), IR = 1.64 (.81–3.37), p = .17 |
| 5 [least deprived] | 107 944 | 27 25.0 (16.8–35.9), IR = 1.13 (1.08–1.19), p = .63 | 5 4.6 (1.7–10.3), Reference | 12 11.1 (6.0–19.2), Reference |

**Note:** Due to very small numbers, those with an infectious etiology or other etiology were not analyzed (n = 4 and n = 7 across all quintiles). Trend was calculated by logistic regression of median Relative Deprivation Index for cases and noncases in each quintile. Abbreviations: CI, confidence interval; IR, incidence ratio.
### Table 5: Proportion of cases of definite or probable new diagnosis of epilepsy with a specific risk factor documented on retrospective chart review in each of the five quintiles, based on relative socioeconomic deprivation, of the defined geographic population

| Quintile        | Febrile seizures | CNS infection | Developmental delay | Family history of epilepsy |
|-----------------|------------------|---------------|---------------------|----------------------------|
|                 | $n$  | %        | %a      | $n$  | %        | %a      | $n$  | %        | %a      | $n$  | %        | %a      |
| 1 [most deprived] |      |          |         |      |          |         |      |          |         |      |          |         |
| Yes             | 11   | 13       | 19      | 1    | 1        | 2       | 11   | 13       | 13      | 14   | 17       | 24      |
| No              | 47   | 55       | 81      | 58   | 68       | 98      | 74   | 87       | 87      | 47   | 55       | 76      |
| Unknown         | 27   | 32       |         | 26   | 31       |         | 0    | 0        |         | 24   | 28       |         |
| 2               |      |          |         |      |          |         |      |          |         |      |          |         |
| Yes             | 5    | 6        | 8       | 1    | 1        | 2       | 8    | 9        | 9       | 15   | 17       | 23      |
| No              | 55   | 63       | 92      | 61   | 70       | 98      | 76   | 88       | 91      | 49   | 56       | 77      |
| Unknown         | 27   | 31       |         | 25   | 29       |         | 3    | 3        |         | 23   | 27       |         |
| 3               |      |          |         |      |          |         |      |          |         |      |          |         |
| Yes             | 3    | 6        | 9       | 1    | 2        | 3       | 9    | 19       | 19      | 7    | 15       | 19      |
| No              | 31   | 65       | 91      | 33   | 69       | 97      | 38   | 79       | 81      | 30   | 62       | 81      |
| Unknown         | 14   | 29       |         | 14   | 29       |         | 1    | 2        |         | 11   | 23       |         |
| 4               |      |          |         |      |          |         |      |          |         |      |          |         |
| Yes             | 1    | 2        | 2       | 0    | 0        | 0       | 6    | 10       | 10      | 10   | 17       | 24      |
| No              | 41   | 68       | 98      | 45   | 75       | 100     | 53   | 88       | 90      | 32   | 53       | 76      |
| Unknown         | 18   | 30       |         | 15   | 25       |         | 1    | 2        |         | 18   | 30       |         |
| 5 [least deprived] |    |          |         |      |          |         |      |          |         |      |          |         |
| Yes             | 1    | 2        | 3       | 1    | 2        | 3       | 5    | 11       | 11      | 4    | 9        | 13      |
| No              | 28   | 61       | 97      | 29   | 62       | 97      | 40   | 87       | 91      | 27   | 59       | 87      |
| Unknown         | 17   | 37       |         | 16   | 35       |         | 1    | 2        |         | 15   | 32       |         |

| Quintile         | Drug or alcohol abuse | Head injury | Cerebrovascular disease | Psychiatric illness |
|------------------|-----------------------|-------------|-------------------------|---------------------|
|                  | $n$  | %        | %a      | $n$  | %        | %a      | $n$  | %        | %a      | $n$  | %        | %a      |
| 1 [most deprived]|      |          |         |      |          |         |      |          |         |      |          |         |
| Yes              | 5    | 6        | 7       | 4    | 5        | 7       | 30   | 35       | 35      | 5    | 6        | 6       |
| No               | 72   | 85       | 93      | 54   | 63       | 93      | 55   | 65       | 65      | 80   | 94       | 94      |
| Unknown          | 8    | 9        |         | 27   | 32       |         | 0    | 0        |         | 0    | 0        |         |
| 2               |      |          |         |      |          |         |      |          |         |      |          |         |
| Yes             | 9    | 10       | 11      | 3    | 3        | 5       | 34   | 40       | 40      | 6    | 7        | 7       |
| No              | 69   | 80       | 89      | 56   | 65       | 95      | 50   | 57       | 60      | 81   | 93       | 93      |
| Unknown         | 9    | 10       |         | 28   | 32       |         | 3    | 3        |         | 0    | 0        |         |
| 3               |      |          |         |      |          |         |      |          |         |      |          |         |
| Yes             | 6    | 12       | 15      | 3    | 6        | 5       | 13   | 27       | 27      | 3    | 6        | 6       |
| No              | 35   | 73       | 85      | 56   | 63       | 95      | 35   | 73       | 73      | 45   | 94       | 94      |
| Unknown         | 7    | 15       |         | 28   | 31       |         | 0    | 0        |         | 0    | 0        |         |
| 4               |      |          |         |      |          |         |      |          |         |      |          |         |
| Yes             | 2    | 3        | 4       | 3    | 2        | 9       | 19   | 32       | 33      | 7    | 12       | 12      |
| No              | 48   | 80       | 96      | 30   | 70       | 91      | 39   | 65       | 64      | 51   | 85       | 85      |
| Unknown         | 10   | 17       |         | 15   | 28       |         | 2    | 3        |         | 2    | 3        |         |
| 5 [least deprived] |    |          |         |      |          |         |      |          |         |      |          |         |
| Yes             | 5    | 11       | 14      | 1    | 6        | 9       | 14   | 30       | 30      | 1    | 2        | 2       |
| No              | 31   | 67       | 86      | 42   | 59       | 91      | 32   | 70       | 70      | 45   | 98       | 98      |
| Unknown         | 10   | 22       |         | 17   | 35       |         | 0    | 0        |         | 0    | 0        |         |

*Note:* “Unknown” indicates that the risk factor was unknown or undocumented.

*Abbreviation: CNS, central nervous system.*

*aPercentage yes or no of those with a documented response.*
different geographical areas, specifically the Carstairs Index, the Welsh Index for Multiple Deprivation, and the Townsend Index. The 2016 Pobal HP Deprivation Index uses more variables than other indices. Furthermore, it aims to assess lack of opportunity as a marker of social deprivation, which is particularly relevant in rural communities, thus allowing comparison of deprivation across the geographic area studied.

Area-level measures of deprivation have potential weaknesses. They do not measure individual-level deprivation and cannot account for the possibility of an individual living in an area of relative deprivation not being deprived themselves. It is reassuring that our results are concordant with prospective incidence studies that assessed socioeconomic deprivation on an individual level. Participant-level data from individual cases would have allowed examination of individual-level socioeconomic deprivation and adjustment for confounding. However, such detail would be difficult to attain for such a large population cohort, and prospectively interviewing each participant was beyond the scope of this study. Similarly, as previously outlined, variability in the documentation of risk factors for seizures and epilepsy is a limitation of our study.

Children and adults in the most socially deprived communities have an excess burden of seizure disorders with lifelong consequences including loss of educational and earning potential. Our study suggests that the increased incidence may be multifactorial. Detailed prospective studies that deeply phenotype participants and their environments are needed to identify risk factors, particularly those that could be modified at the individual, community, or policy level. The effects of seizures and epilepsy have lifelong implications and deserve further study and modification where possible.

**AUTHOR CONTRIBUTIONS**

Eimer M. Maloney: Conceptualization, data curation, formal analysis, investigation, methodology, writing—original draft. Paul Corcoran: Methodology, writing—review and editing. Daniel J. Costello: Conceptualization, project administration, supervision, writing—review and editing. Éilis J. O’Reilly: Conceptualization, project administration, supervision, formal analysis, validation, writing—review and editing.

**ACKNOWLEDGMENTS**

The authors would like to thank all hospital-based medical, nursing, neurophysiology, radiology and medical records administrative staff as well as community-based G.P.s and nursing home staff who contributed and responded to the study. Open access funding provided by IReL. [Correction added on 05 July, 2022, after first online publication: IReL funding statement has been added.]

**CONFLICT OF INTEREST**

None of the authors has any conflict of interest to disclose. We confirm that we have read the Journal’s position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

**DATA AVAILABILITY STATEMENT**

Anonymized data can be shared by request from any qualified investigator.

**ORCID**

Eimer M. Maloney https://orcid.org/0000-0002-1536-2026

Éilis J. O’Reilly https://orcid.org/0000-0002-6802-9956

**REFERENCES**

1. Morgan CL, Ahmed Z, Kerr MP. Social deprivation and prevalence of epilepsy and associated health usage. J Neurol Neurosurg Psychiatry. 2000;69(1):13–7.

2. Kaiboriboon K, Bakaki PM, Lhatoo SD, Koroukian S. Incidence and prevalence of treated epilepsy among poor health and low-income Americans. Neurology. 2013;80(21):1942–9.

3. Magnusson C. High-resolution mapping of epilepsy prevalence, ambulance use, and socioeconomic deprivation in an urban area of Sweden. Epilepsia. 2019;60(10):2060–7.

4. Pickrell WO, Lacey AS, Bodger OG, Demmler JC, Thomas RH, Lyons RA, et al. Epilepsy and deprivation, a data linkage study. Epilepsia. 2015;56(4):585–91.

5. Heaney DC, MacDonald BK, Everitt A, Stevenson S, Leonardi GS, Wilkinson P, et al. Socioeconomic variation in incidence of epilepsy: prospective community based study in south east England. BMJ. 2002;325(7371):1013–6.

6. Benn EK, Hauser WA, Shih T, Leary L, Bagiella E, Dayan P, et al. Estimating the incidence of first unprovoked seizure and newly diagnosed epilepsy in the low-income urban community of northern Manhattan, New York City. Epilepsia. 2008;49(8):1431–9.

7. Forsgren L, Nystrom L. An incident case-referent study of epileptic seizures in adults. Epilepsy Res. 1990;6(1):66–81.

8. Reading R, Haynes R, Beach R. Deprivation and incidence of epilepsy in children. Seizure. 2006;15(3):190–3.

9. Li X, Sundquist J, Zoller S, Sundquist K. Neighborhood, family, and childhood and adolescent epilepsy: a nationwide epidemiological study from Sweden. Seizure. 2014;23(1):62–8.

10. Hesdorffer DC, Tian H, Anand K, Hauser WA, Ludvigsson P, Olafsson E, et al. Socioeconomic status is a risk factor for epilepsy in Icelandic adults but not in children. Epilepsia. 2005;46(8):1297–303.

11. Maloney EM, Chaila E, O’Reilly EJ, Costello DJ. Incidence of first seizures, epilepsy, and seizure mimics in a geographically defined area. Neurology. 2020;95(5):e576–90.

12. Central Statistics Office. Census of population. 2016. https://wwwcsoie/en/census/census2016reports/census2016smallareapopulationstatistics/. Accessed Jan 2018.

13. Maloney EM, Chaila E, O’Reilly EJ, Costello DJ. Application of recent international epidemiological guidelines to a prospective
study of the incidence of first seizures, newly-diagnosed epilepsy and seizure mimics in a defined geographic region in Ireland. Neuroepidemiology. 2019;53(3–4):225–36.

14. Thurman DJ, Beghi E, Begley CE, Berg AT, Buchhalter JR, Ding D, et al. Standards for epidemiologic studies and surveillance of epilepsy. Epilepsia. 2011;52(Suppl 7):2–26.

15. Fisher RS, van Emde BW, Blume W, Elger C, Genton P, Lee P, et al. Epileptic seizures and epilepsy: definitions proposed by the International League Against Epilepsy (ILAE) and the International Bureau for Epilepsy (IBE). Epilepsia. 2005;46(4):470–2.

16. Fisher RS, van Emde BW, Blume W, Elger C, Genton P, Lee P, et al. ILAE official report: a practical clinical definition of epilepsy. Epilepsia. 2014;55(4):475–82.

17. Stroink H, Brouwer OF, Arts WF, Geerts AT, Peters ACB, van Donselaar CA. The first unprovoked, untreated seizure in childhood: a hospital based study of the accuracy of the diagnosis, rate of recurrence, and long term outcome after recurrence. Dutch Study of Epilepsy in Childhood. J Neurol Neurosurg Psychiatry. 1998;64(5):595–600.

18. Krumholz A, Shinnar S, French J, Gronseth G, Wiebe S. Evidence-based guideline: management of an unprovoked first seizure in adults: report of the Guideline Development Subcommittee of the American Academy of Neurology and the American Epilepsy Society. Neurology. 2015;85(17):1526–7.

19. Hauser WA, Rich SS, Annegers JF, Anderson VE. Seizure recurrence after a 1st unprovoked seizure: an extended follow-up. Neurology. 1990;40(8):1163–70.

20. Bergey GK. Management of a first seizure. Continuum (Minneap Minn). 2016;22(1 Epilepsy):38–50.

21. Hesdorffer DC, Benn EK, Cascino GD, Hauser WA. Is a first acute symptomatic seizure epilepsy? Mortality and risk for recurrence. Epilepsia. 2009;50(5):1102–8.

22. Hesdorffer DC, Hauser WA, Annegers JF, Kokmen E, Rocca WA. Dementia and adult-onset unprovoked seizures. Neurology. 1996;46(3):727–30.

23. Stosser S, Bockler S, Ludolph AC, Kassubek J, Neugebauer H. Juxtacortical lesions are associated with seizures in cerebral small vessel disease. J Neurol. 2019;266(5):1230–5.

24. Beghi E, Carpio A, Forsgren L, Hesdorffer DC, Malmgren K, Sander JW, et al. Recommendation for a definition of acute symptomatic epilepsy. Epilepsia. 2010;51(4):671–5.

25. Scheffer IE, Berkovic S, Capovilla G, Connolly MB, French J, Guilhoto L, et al. ILAE classification of the epilepsies: position paper of the ILAE Commission for Classification and Terminology. Epilepsia. 2017;58(4):512–21.

26. Haase T, J Pratschke. The 2016 Pobal HP Deprivation Index. 2017. www.trutshaase.eu. Accessed 14 May 2019.

27. Linehan C, Kerr MP, Walsh PN, Brady G, Kelleher C, Delanty N, et al. Examining the prevalence of epilepsy and delivery of epilepsy care in Ireland. Epilepsia. 2010;51(5):845–52.

28. Liao CC, Chang HC, Yeh CC, Chou YC, Chiu WT, Chen TL. Socioeconomic deprivation and associated risk factors of traumatic brain injury in children. J Trauma Acute Care Surg. 2012;73(5):1327–31.

29. Naess O, Piro FN, Naftstad P, Smith GD, Leyland AH. Air pollution, social deprivation, and mortality: a multilevel cohort study. Epidemiology. 2007;18(6):686–94.

30. Cakmak S, Dales RE, Vidal CB. Air pollution and hospitalization for epilepsy in Chile. Environ Int. 2010;36(6):501–5.

31. Xu C, Fan YN, Kan HD, Chen RJ, Liu JH, Li YF, et al. The novel relationship between urban air pollution and epilepsy: a time series study. PLOS One. 2016;11(8):e0161992.

32. Chiang KL, Lee YJ, Chang YM Lee YJ, Chang YM, Kuo FC, et al. The effect of weather, air pollution and seasonality on the number of patient visits for epileptic seizures: a population-based time-series study. Epilepsy Behav. 2021;115:107487.

33. Fisher RS, Cross JH, French JA, Higurashi N, Hirsch E, Jansen FE, et al. Operational classification of seizure types by the International League Against Epilepsy: position paper of the ILAE Commission for Classification and Terminology. Epilepsia. 2017;58(4):522–30.

34. Lewer D, Meier P, Beard E, Boniface S, Kaner E. Unravelling the alcohol harm paradox: a population-based study of social gradients across very heavy drinking thresholds. BMC Public Health. 2016;16:599.

35. Linton SL, Haley DF, Hunter-Jones J, Ross Z, Cooper HLF. Social causation and neighborhood selection underlie associations of neighborhood factors with illicit drug-using social networks and illicit drug use among adults relocated from public housing. Soc Sci Med. 2017;185:81–90.

36. Ramsay SE, Morris RW, Whincup PH, Subramanian SV, Papacosta AO, Lennon LT, et al. The influence of neighbourhood-level socioeconomic deprivation on cardiovascular disease mortality in older age: longitudinal multilevel analyses from a cohort of older British men. J Epidemiol Community Health. 2015;69(12):1224–31.

37. Gunawardane N, Fields M. Acute symptomatic seizures and provoked seizures: to treat or not to treat? Curr Treat Options Neurol. 2018;20(10):41.

38. Ward FL, O’Kelly P, Donohue F, O’Haiseadha C, Haase T, Pratschke J, et al. The influence of socioeconomic status on patient survival on chronic dialysis. Hemodial Int. 2015;19(4):601–8.

39. Ward FL, O’Kelly P, Donohue F, O’Haiseadha C, Haase T, Pratschke J, et al. Influence of socioeconomic status on allograft and patient survival following kidney transplantation. Nephrolology (Carlton). 2015;20(6):426–33.

40. Allers K, Essue BM, Hackett ML, Muhunthan J, Anderson CS, Pickles K, et al. The economic impact of epilepsy: a systematic review. BMC Neurol. 2015;15:245.

SUPPORTING INFORMATION
Additional supporting information may be found in the online version of the article at the publisher’s website.

How to cite this article: Maloney EM, Corcoran P, Costello DJ, O’Reilly EJ. Association between social deprivation and incidence of first seizures and epilepsy: A prospective population-based cohort. Epilepsia. 2022;63:2108–2119. https://doi.org/10.1111/epi.17313