INTRODUCTION

Epilepsy incidence and prevalence rates in the adult population <65 years of age has been decreasing in high-income countries [1]. In Finland, a previous study based on drug reimbursement data reported that between 1986 and 2002, the incidence of epilepsy decreased in both children and adults 15-64 years of age, but increased in those older than 65 years [2]. However, another study utilizing inpatient admission data reported that between 1973 and 2013, epilepsy incidence increased in those older than 65 years, whereas there was no change in incidence in younger age groups [3]. Information on these trends is important in guiding public health
Measures in epilepsy prevention and health care in treatment organizations. Therefore, in this study, we updated the data and trends on incidence of adult onset epilepsy.

**METHODS**

The open statistics of the Social Insurance Institution of Finland (KELA), Finland’s national authority, were searched for changes in the annual numbers of new drug reimbursement rights for epilepsy in people ≥20 years old (code 111, which is only granted for epilepsy) between the years 1986 and 2019. All persons with newly diagnosed epilepsy are eligible for antiseizure drug reimbursement, which is also routinely applied for, necessitating a detailed statement by a neurologist and investigations at a specialist clinic. The statement is checked and approved by specialist physicians at the reimbursement institution KELA before the right is granted. The epilepsy diagnosis in Finland is made according to national guidelines, which have been updated according to the changes in International League Against Epilepsy (ILAE) epilepsy definitions. To calculate incidence rates, population data were obtained from Statistics Finland, the Finnish census entity. Changes in the population structure were accounted for by calculating both age- and gender-specific rates and age-standardized rates. European Standard Population 2013 and the direct method were used for age standardization. Relationships between continuous variables were analyzed using Pearson or Spearman correlation as appropriate. Poisson distribution was used to calculate 95% confidence intervals (CIs) for incidence and prevalence. Because the study is based on openly available anonymized data, no institutional review or permissions were needed or sought.

**RESULTS**

Altogether, 77,939 people were granted a new code 111 reimbursement right during the study period (45.7% to women). Overall crude epilepsy incidence was therefore 57.4/100,000 (95% CI = 57.0–57.8) person-years, increasing nonlinearly from 58.5/100,000 person-years in 1986 to 63.3/100,000 person-years in 2019 ($r = 0.62$, $p = 0.00009$; Figure 1). Overall age-standardized incidence was 51.6/100,000 person-years and also increased from 48.4/100,000 person-years in 1986 to 53.0/100,000 person-years in 2019 ($r = 0.65$, $p = 0.00003$; Figure 1). Incidence increased both in men (from 66.4 to 71.6/100,000; $r = 0.51$, $p = 0.002$) and women (from 51.5 to 55.3/100,000; $r = 0.68$, $p < 0.00001$; Figure 1). The mean male to female incidence rate ratio was 1.28 (95% CI = 1.26–1.30, range = 1.15–1.41), with a decreasing trend during the study period ($r = -0.47$, $p = 0.006$; Figure 1). Incidence decreased in those aged 20–59 years but increased in all older age groups (Table 1), a development similar between the sexes (Figure 1).

**DISCUSSION**

This nationwide registry study showed that, over the past 34 years in Finland, the incidence of adult onset epilepsy increased in people...
TABLE 1 Annual epilepsy incidence by age group

| Age Group | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|-----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 20-29 yrs | 64.4 | 59.0 | 52.4 | 50.3 | 56.9 | 69.2 | 46.6 | 42.3 | 43.4 | 52.2 | 55.5 | 53.7 | 49.1 | 47.3 | 36.3 | 32.6 | 40.0 | 38.0 | 30.4 | 34.8 | 35.6 | 46.8 | 41.4 | 44.4 | 53.5 | 41.3 | 45.1 | 41.0 | 46.0 | 41.8 | 48.0 | 41.3 |
| 30-39 yrs | 49.2 | 43.5 | 41.5 | 44.6 | 40.0 | 55.1 | 40.5 | 46.6 | 34.6 | 39.1 | 45.0 | 42.6 | 53.4 | 29.4 | 33.4 | 30.9 | 38.9 | 28.8 | 32.8 | 31.1 | 35.7 | 30.1 | 35.5 | 34.5 | 28.8 | 35.1 | 30.0 | 32.0 | 29.9 | 28.7 | 25.8 | 30.4 |
| 40-49 yrs | 51.6 | 43.1 | 46.3 | 42.6 | 46.2 | 55.5 | 45.7 | 55.3 | 42.3 | 44.8 | 41.1 | 46.3 | 40.6 | 43.9 | 40.4 | 39.3 | 35.6 | 33.5 | 30.6 | 37.7 | 37.5 | 30.7 | 37.4 | 36.2 | 30.2 | 42.1 | 37.8 | 30.3 | 38.8 | 34.5 | 35.9 |
| 50-59 yrs | 66.0 | 60.5 | 60.0 | 59.4 | 64.1 | 68.1 | 55.7 | 64.7 | 56.8 | 51.8 | 57.5 | 56.0 | 56.3 | 51.0 | 48.1 | 46.6 | 51.1 | 54.2 | 51.7 | 56.5 | 56.6 | 62.5 | 52.7 | 54.7 | 54.8 | 57.6 | 54.6 | 55.7 | 51.4 | 51.2 | 52.4 | 50.1 |
| 60-69 yrs | 69.5 | 63.8 | 63.7 | 68.4 | 61.9 | 83.6 | 75.2 | 77.9 | 60.0 | 62.3 | 71.4 | 59.3 | 77.6 | 62.9 | 73.5 | 68.8 | 78.8 | 72.6 | 87.7 | 85.8 | 70.1 | 81.5 | 80.0 | 81.5 | 81.6 | 86.0 | 80.0 | 89.9 | 83.3 | 86.8 | 75.5 |
| 70-79 yrs | 64.4 | 64.6 | 64.5 | 61.5 | 66.6 | 79.3 | 82.1 | 76.8 | 80.7 | 85.8 | 77.6 | 81.4 | 87.7 | 80.1 | 80.0 | 76.8 | 84.6 | 81.4 | 81.0 | 82.0 | 81.0 | 81.2 | 113.1 | 108.9 | 112.4 | 128.5 | 123.7 | 132.4 | 137.4 | 128.3 | 132.0 | 130.0 |
| >80 yrs   | 36.8 | 39.7 | 35.6 | 31.6 | 41.8 | 47.7 | 57.6 | 44.6 | 57.9 | 55.6 | 47.6 | 51.8 | 59.8 | 55.8 | 50.0 | 57.0 | 62.3 | 62.7 | 76.8 | 67.9 | 106.6 | 88.0 | 110.0 | 110.7 | 109.8 | 100.7 | 148.5 | 145.6 | 139.3 | 164.2 | 0.97 | 0.000003 |

Abbreviations: p, probability value for Pearson or Spearman correlation; r, correlation coefficient.

Epilepsy incidence trends in Finland are repeating the pattern with a lag of approximately 15 years. In recent studies on epilepsy incidence in Ireland [2,3], Finland is repeating the pattern in cerebrovascular disease was connected with increasing incidence of epilepsy in the elderly [11]. Unfortunately, we do not have etiology data for our current data show that around 2005, incidence began to increase in all age groups. Results from previous studies have suggested that this may not be the case with epilepsy in the elderly [2,11]. Unfortunately, we do not have etiology data for our previous reports from Finland (1,2,4). One previous Finnish study reported increasing incidences between 1973 and 2013 [3]. The study used inpatient admission data, which were suggested as more reliable than the previously used methodologies. However, contrary to what this study’s authors stated, adults with seizures including those newly diagnosed with epilepsy are often only monitored in Finnish emergency rooms, for which epilepsy drug reimbursement data were obtained from, has not been studied. Epilepsy drug reimbursement data are also often made during outpatient appointments. Therefore, it is unclear how accurate adult epilepsy incidence results based on inpatient data are. Furthermore, the validity of epilepsy diagnoses in the Care Register for Health Care, the database the epilepsy data were obtained from, has not been studied. Epilepsy drug reimbursement data, as used in an earlier study [2] and the current one, therefore appear more robust compared to administrative inpatient data. Researchers have concluded that epilepsy prevention efforts have failed [3], but our results suggest that this may not be the case with the working aged.
actively recognized and reported in the elderly, facilitated by the new operational definition of epilepsy by the ILAE in 2014 [11].

Epilepsy incidence is generally higher in men compared to women [1], as observed in the current data. However, we also found that the male to female incidence ratio slightly decreased during the study period. The reasons for this are unclear, but differing risk factor trajectories are one possible explanation. For example, smoking has declined much more among Finnish men compared to women [6]. Smoking predisposes individuals to, among other things, stroke and cancer, which are both important epilepsy etiologies in adults and the elderly. First-ever stroke incidence appears to have decreased more in elderly men compared to elderly women [7]. Moreover, traumatic brain injuries seem to have increased more in older women and also appear to generate more severe consequences than in elderly men [5].

This retrospective registry study was performed using freely available, anonymized data from the national provider KELA. Therefore, individual patient data were unavailable. As the study was based on administrative registry data that have not been collected for clinical or scientific use, some cases may have been missed because of erroneous diagnoses or administrative coding or because the reimbursement right had not been sought. Moreover, there have been no studies on the validity of epilepsy drug reimbursement decisions in Finland. However, the reimbursement right process suggests that this should be rather high. The study period was also extensive, covering 34 years during which, to our knowledge, there were no changes in how epilepsy reimbursement decisions are made. However, the definition of epilepsy has evolved, which may have influenced the results, although it seems that the 2014 introduction of the current definition of epilepsy did not trigger the previously predicted increases in incidence rates [12]. Data from Ireland show that this change made diagnosing epilepsy much more likely, especially in the elderly [11]. However, in Finland, the trend of increasing epilepsy incidence in the elderly had already started a decade earlier and seems to have leveled off during the past few years, and the same applies to have happened in Denmark even earlier [10]. These discrepancies call for further studies and international comparisons. The data in the current study are nationwide, with virtually complete coverage of diagnosed cases. The results are likely to be generalizable to other high-income countries.

In conclusion, the incidence of epilepsy in Finland slightly declined in adults 20–59 years old, but markedly increased in those older than 60 years between 1986 and 2019, with similar trends between sexes. As the incidence of epilepsy in the elderly increases and populations age, the need for neurological services grows.

CONFLICT OF INTEREST
J.O.T.S. reports personal fees from Merck, Pfizer, and Sanofi, non-financial support from Abbvie, and other support from Orion Corporation, outside the submitted work. R.K. reports grants from Vaajasalo Foundation, Saastamoinen Foundation, and Academy of Finland, other support from UCB, and personal fees from UCB, Eisai, Orion Corporation, Marinus Pharma, OmaMedical, Sandoz, and Sanofi, outside the submitted work.

AUTHOR CONTRIBUTIONS
Jussi O. T. Sipilä: Conceptualization (lead), data curation (lead), formal analysis (lead), investigation (equal), methodology (equal), project administration (lead), resources (lead), visualization (lead), writing—original draft (lead). Reetta Kälviäinen: Conceptualization (supporting), formal analysis (supporting), investigation (equal), methodology (equal), supervision (lead), writing—review & editing (lead).

ETHICAL APPROVAL
Ethical approval and informed consent were not required because the study was based on anonymous public data.

DATA AVAILABILITY STATEMENT
The data used in this study are openly available at http://raporttit.kela.fi/ibi_apps/WFServlet?IBIF_ex=NIT084AL&YKI_EL=0.

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How to cite this article: Sipilä JOT, Kälviäinen R. Adult onset epilepsy incidence in Finland over 34 years: A nationwide registry study. Eur J Neurol. 2022;29:605–608. https://doi.org/10.1111/ene.15141