Epidemiology of dementia: prevalence and incidence estimates using validated electronic health records from primary care

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Purpose: Updated estimates of incidence and prevalence of dementia are crucial to ensure adequate public health policy. However, most of the epidemiological studies in the population in Spain were conducted before 2010. This study assessed the validity of dementia diagnoses recorded in electronic health records contained in a large primary-care database to determine if they could be used for research purposes. Then, to update the epidemiology of dementia in Catalonia (Spain), we estimated crude and standardized prevalence and incidence rates of dementia in Catalonia in 2016.

Methods: The System for the Development of Research in Primary Care (SIDIAP) database contains anonymized information for >80% of the Catalan population. Validity of dementia codes in SIDIAP was assessed in patients at least 40 years old by asking general practitioners for additional evidence to support the diagnosis. Crude and standardized incidence and prevalence (95% CI) in people aged ≥65 years were estimated assuming a Poisson distribution.

Results: The positive predictive value of dementia diagnoses recorded in SIDIAP was estimated as 91.0% (95% CI 87.5%–94.5%). Age- and sex-standardized incidence and prevalence of dementia were 8.6/1,000 person-years (95% CI 8.0–9.3) and 5.1% (95% CI 4.5%–5.7%), respectively.

Conclusion: SIDIAP contains valid dementia records. We observed incidence and prevalence estimations similar to recent face-to-face studies conducted in Spain and higher than studies using electronic health data from other European populations.

Keywords: family physician, accuracy, quality, positive predictive value, electronic medical record, real-world data

Introduction
Dementia affects about 47 million people worldwide and is related to dependence, poor quality of life, institutionalization, and mortality.1 Age is the main risk factor for dementia, and the world population is aging; therefore, the number of people affected by dementia is expected to increase to 131 million in 2050, resulting in huge social and economic costs.1 Population-based epidemiological estimates of its prevalence and incidence is crucial to plan and budget health services and evaluate its economic burden. Therefore, robust and up-to-date estimates are needed to support the creation of useful public policies on dementia.2 However, updated estimates of prevalence and incidence in the European population are scarce,1 eg, in Spain, most of the studies collected data in the 1990s or 2000s, and to our knowledge, only four used data collected during the past 10 years.3–6 High economic costs of door-to-door surveys or questionnaire-based studies may contribute to the difficulty of updating estimates of prevalence and incidence of dementia.
Electronic health records emerged as a new opportunity to study the epidemiology of dementia: prevalence and incidence-rate estimates can be updated at low cost using data routinely collected in health care settings. Indeed, the use of electronic medical databases to assess the epidemiology of dementia has been increasing at the European level and in many developed countries, such as Canada and the Netherlands. However, the accuracy of dementia records in routinely collected health care data sets is always a concern, and cohorts should ideally conduct their own setting-specific validation. This concern is especially apparent for electronic health records collected in primary care, because accuracy of dementia diagnoses recorded by general practitioners has been considered low. Nevertheless, a recent systematic review reported high positive predictive values (PPVs) (0.83 or higher) when identifying dementia cases in primary-care data, indicating that dementia codes in those primary-care databases were sufficiently accurate to be used for research purposes.

We thus used data from a large primary-care database to describe the epidemiology of dementia in Catalonia, southern Europe. First, we assessed the validity of dementia diagnoses recorded in the database to determine if they could be used for research purposes. Then, we estimated crude and standardized prevalence and incidence rates of dementia in Catalonia in 2016, in order to update the epidemiological estimates.

Methods

This population-based study was approved by the Clinical Research Ethics Committee, Primary Care Research Institute – IDIAP Jordi Gol. Data were obtained from the System for the Development of Research in Primary Care (SIDIAP) database, which contains routine records of consultations from ~275 general-care practices belonging to the National Health Service of Catalonia (Institut Català de la Salut). SIDIAP contains anonymized longitudinal medical records containing data on demographics, symptoms, diagnoses, and prescriptions for about 6 million people (~80% of the Catalan population, 15% of the Spanish population). We defined dementia diagnoses using the following codes from the International Classification of Diseases, Tenth revision (ICD10): dementia in Alzheimer’s disease (F00), vascular dementia (F01), dementia in other diseases classified elsewhere (F02.8), unspecified dementia (F03), Alzheimer’s disease (G30), Lewy body disease (G31.8), or frontotemporal dementia (G31.0). SIDIAP is linked with the pharmacy-invoicing database provided by the National Health Service of Catalonia and medications are recorded using the Anatomical Therapeutic Chemical (ATC) codes. We considered as treated those patients who had a prescription or billing for anticholinesterases (N06DA) or memantine (N06D × 01). We used outcomes recorded in SIDIAP to describe dementia assessment in the Catalan primary-care system, because clinical practice might influence the identification of dementia cases, and this would affect estimates of prevalence and incidence rates.

In particular, we identified the number of persons who were institutionalized, attended by the home-care program, had a record of cognitive assessment, or had a record of functional ability and independence assessment. Cognitive assessment was defined as at least one Mini-Mental Status Examination or Pfeiffer test (Spanish versions) score ≤23 or ≥3, respectively, considered to suggest cognitive impairment. Assessment of functional ability and independence was defined as at least one recorded score on the Barthel Index, Lawton Scale, Katz Index, or Blessed Dementia Rating Scale. Low functional ability or dependence was considered when the score was <90 on the Barthel Index, <3 in men and <5 in women on the Lawton Scale, ≥2 on the Katz Index, or ≥4 on the Blessed Dementia Rating Scale.

Validation of dementia diagnoses

To assess accuracy of dementia diagnoses recorded in SIDIAP, we emailed a short survey to general practitioners asking about the current status of the diagnosis (Figure S1), a method used previously in validations of dementia diagnosis. We invited general practitioners of the Agency of Clinical Research Management in Primary Care (AGICAP), associated with the IDIAP Jordi Gol to participate in the validation study. AGICAP general practitioners received training and had experience in recruitment of patients in clinical trials and in review of diagnoses recorded in the electronic medical history. We emailed an online survey to general practitioners who agreed to participate, asking for further evidence to confirm the diagnosis of all their patients aged at least 40 years who had a dementia code recorded in SIDIAP (ICD10). The survey remained available online for 1 month for general practitioners to evaluate dementia diagnoses. In order to enhance the response rate, we offered a small monetary incentive and sent one follow-up email to nonresponding general practitioners to remind them to complete the questionnaire. The online survey examined whether or not the diagnosis was made by a specialist, whether or not the diagnosis fulfilled the Diagnostic and Statistical Manual of Mental Disorders (DSM) IV or ICD10 diagnosis criteria, which symptoms were observed, subtype and severity of dementia, and if the diagnosis was considered to be incor-
rect, evolved, or uncertain due to incomplete information (Figure S1). When applicable, additional information about the score achieved in cognitive and functional tests was requested (Figure S1). We defined patients as true cases if they were diagnosed by a specialist (eg, neurologist or psychiatrist), by cognitive or functional tests, or by clinical opinion of the general practitioner and DSM-IV or ICD10 diagnostic criteria were fulfilled (Figure 1). Patients were defined as false cases when the diagnosis was considered by the general practitioner not to fulfill DSM-IV or ICD10 diagnostic criteria, was based on inconsistent evidence, had evolved, or was incorrect (Figure 1).

Incidence and prevalence
The study population included patients aged at least 65 years who were registered in SIDIAP. We defined a case as any patient having an ICD10 diagnosis of dementia or an ATC code of pharmacological treatment related to dementia recorded in SIDIAP. In Catalonia, the prescription of antidementia drugs is requested by the general practitioner, but until 2014 required approval from the advisory board, a group of experts who evaluated all patients with dementia recommended for pharmacological treatment. Since 2014, approval has been determined by a geriatrician, psychiatrist, or neurologist. Since all treated patients had been evaluated previously by specialists, we considered them true cases. To estimate the incidence rate, persons who were alive in 2016 according to SIDIAP records were included. Incident cases were defined as dementia patients diagnosed or treated during 2016. Patients diagnosed with dementia or treated with antidementia drugs before January 1, 2016 were excluded. To estimate dementia prevalence, persons who had SIDIAP records and were alive as of December 31, 2016 were included. Patients who moved away or died before that date were excluded. Prevalent cases were defined as patients diagnosed or treated as of December 31, 2016.

Statistical analyses
We estimated PPV and 95% CI of dementia diagnosis using data from the survey of general practitioners. PPV is an indicator of the probability that a person with a record of dementia diagnosis in SIDIAP truly had the disease. A higher PPV indicated better accuracy of the dementia records in SIDIAP. In Catalonia, the prescription of antidementia drugs is requested by the general practitioner, but until 2014 required approval from the advisory board, a group of experts who evaluated all patients with dementia recommended for pharmacological treatment. Since 2014, approval has been determined by a geriatrician, psychiatrist, or neurologist. Since all treated patients had been evaluated previously by specialists, we considered them true cases. To estimate the incidence rate, persons who were alive in 2016 according to SIDIAP records were included. Incident cases were defined as dementia patients diagnosed or treated during 2016. Patients diagnosed with dementia or treated with antidementia drugs before January 1, 2016 were excluded. To estimate dementia prevalence, persons who had SIDIAP records and were alive as of December 31, 2016 were included. Patients who moved away or died before that date were excluded. Prevalent cases were defined as patients diagnosed or treated as of December 31, 2016.

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(denominator). Results were stratified by sex and age-group. We also performed sensitivity analyses to explore the robustness of our results. By extrapolating figures to the worst-case scenario, we replicated the analyses considering both evaluated and unevaluated diagnoses of dementia. PPV was replicated, including in the numerator all diagnoses of dementia confirmed by the general practitioners or with evidence of treatment with antidementia drugs, and in the denominator all recorded diagnoses of dementia included in the validation study (evaluated or not by general practitioners).

To describe the study population and primary-care settings, we used percentages for categorical variables and means (SD) or medians (IQR) for continuous variables. We estimated overall crude prevalence and incidence rates, and 95% CI was calculated assuming a Poisson distribution. We stratified the prevalence and incidence estimates by sex and age-group. We used the direct method to estimate age- and sex-standardized prevalence and incidence of dementia. The 2013 revision of the European standard population served as the basis for adjustment (EU27/European Free Trade Association standard population: 22 weights of 0.28, 0.26, 0.21, 0.13, 0.08, and 0.05 for age-groups 65–69, 70–74, 75–79, 80–84, 85–89, and ≥90 years, and 0.5 for both men and women). We used the official 2015 population estimate of 11,045,521 citizens in Spain aged ≥65 years (http://www.ine.es).

Finally, we calculated age-standardized rates for women and men and sex-standardized rates for age-groups separately. We used the likelihood-ratio test to examine the age–sex interaction. All analyses were performed using R software version 3.5.2. 23

**Results**

**Validation of dementia diagnoses**

Surveys were sent to 42 general practitioners, of which 29 participated in the validation study (response rate 69%). These 29 general practitioners had records of 374 patients with a dementia diagnosis, of which 256 diagnoses were evaluated during the 1-month validation period. Among the 118 unconfirmed dementia diagnoses, 58 of the patients were treated with antidementia drugs and 60 were untreated. General practitioners evaluated 256 dementia diagnoses and considered 233 true cases: 209 patients diagnosed by a specialist and 24 patients who fulfilled the DSM-IV or ICD10 diagnostic criteria. We identified 23 false cases: 21 considered evolved, incorrect, or uncertain diagnoses and two not fulfilling DSM-IV or ICD10 diagnostic criteria. Therefore, the PPV of dementia codes registered in SIDIAP was 91.0% (95% CI 87.5%–94.5%). Results stratified by age and sex provided similar results: PPV was estimated as 89.8% (95% CI 85.2%–94.4%) for women (n=166), 93.3% (95% CI 88.1%–98.5%) for men (n=90), 90.3% (95% CI 85.6%–95.0%) for persons aged <80 years (n=154), and 92.1% (95% CI 86.9%–97.3%) for persons at least 80 years old (n=102).

General practitioners evaluated 128 diagnoses of patients who had both a diagnosis and pharmacological treatment for dementia recorded in SIDIAP, and 99% of these were confirmed as true cases. We replicated the PPV estimates, adding the unconfirmed cases as true cases if the diagnosed patient had been treated with antidementia drugs or as false cases if they had not been treated. In this worst-case scenario, the PPV estimate included 291 true cases in the numerator (233 dementia diagnoses evaluated and confirmed by general practitioners, and 58 unconfirmed dementia diagnoses in patients being treated for the disease) and 374 dementia diagnoses in the denominator (256 evaluated by general practitioners and 118 unconfirmed). The resulting PPV was 77.8% (95% CI 73.6%–82.0%).

**Incidence and prevalence**

For 2016, we obtained data for 1,035,046 persons, mainly women (56.2%), from urban areas (80.9%) and 75.7 (7.9) years old on average. We obtained 1,008,755 person-years detected 9,596 incident cases, of which 8,553 had been diagnosed and 1,043 undiagnosed but treated with antidementia drugs. Table S1 provides further details of the estimated population to estimate incidence rates. The crude incidence of dementia was estimated at 9.5/1,000 person-years (95% CI 9.3–9.7), sex-standardized incidence at 9.3/1,000 person-years (95% CI 9.0–9.6), age-standardized incidence at 8.8/1,000 person-years (95% CI 8.4–9.2), and age- and sex-standardized incidence at 8.6/1,000 person-years (95% CI 8.0–9.3). The incidence rate was higher among women than men, and increased with age: it was about 25 times higher in people older than 90 years than in people aged 65–69 years (Table 1). We found a significant age–sex interaction (P<0.001), and age-related increase in incidence was more pronounced in women than in men (Figure 2, Table S2).

To estimate dementia prevalence, we obtained data on 1,048,956 persons recorded in SIDIAP on December 31, 2016. Participants were mainly women (57.2%) and predominantly from urban areas (80.9%). Mean (SD) age was 75.9 (7.9) years. Table S3 shows the medical conditions of the study population used to estimate dementia prevalence. We found 63,117 prevalent cases, of which 55,951 had been diagnosed and 7,166 undiagnosed but treated with antidementia drugs. The median duration of dementia in prevalent...
Table 1 Crude and standardized incidence rates of dementia (per 1,000 person-years) in people aged ≥65 years in Catalonia (Spain) in 2016, stratified by sex and age

<table>
<thead>
<tr>
<th>Groups</th>
<th>Cases</th>
<th>Person/years</th>
<th>Crude incidence (95% CI)</th>
<th>Standardized incidence (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole population</td>
<td>9,596</td>
<td>1,008,755</td>
<td>9.5 (9.3–9.7)</td>
<td>8.6 (8.0–9.3)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>6,218</td>
<td>567,836</td>
<td>11.0 (10.7–11.2)</td>
<td>9.4 (8.9–10.0)</td>
</tr>
<tr>
<td>Men</td>
<td>3,378</td>
<td>440,919</td>
<td>7.7 (7.4–7.9)</td>
<td>7.8 (7.2–8.5)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65–69 years</td>
<td>330</td>
<td>282,876</td>
<td>1.2 (1.0–1.3)</td>
<td>1.2 (1.0–1.4)</td>
</tr>
<tr>
<td>70–74 years</td>
<td>920</td>
<td>240,706</td>
<td>3.8 (3.6–4.1)</td>
<td>3.8 (3.5–4.2)</td>
</tr>
<tr>
<td>75–79 years</td>
<td>1,574</td>
<td>173,703</td>
<td>9.1 (8.6–9.5)</td>
<td>9.0 (8.4–9.6)</td>
</tr>
<tr>
<td>80–84 years</td>
<td>2,667</td>
<td>159,296</td>
<td>16.7 (16.1–17.4)</td>
<td>16.4 (15.5–17.3)</td>
</tr>
<tr>
<td>85–89 years</td>
<td>2,490</td>
<td>97,631</td>
<td>25.5 (24.5–26.5)</td>
<td>24.9 (23.5–26.4)</td>
</tr>
<tr>
<td>≥90 years</td>
<td>1,615</td>
<td>54,543</td>
<td>29.6 (28.2–31.1)</td>
<td>28.6 (26.5–30.8)</td>
</tr>
</tbody>
</table>

Note: *Age- and sex-standardized; †age-standardized; ‡sex-standardized.

cases was 3.77 (IQR 1.67–6.50) years. Table 2 describes the dementia assessment in the Catalan primary settings. We estimated crude prevalence as 6.0% (95% CI 6.0%–6.1%), sex-standardized prevalence 5.8% (95% CI 5.7%–5.9%), age-standardized prevalence 5.3% (95% CI 5.0%–5.6%), and both sex- and age-standardized prevalence 5.1% (95% CI 4.5%–5.7%). Dementia prevalence was higher in women than men and increased with age (Table 3). The age-related increase in prevalence was significantly higher in women than in men, with a P-value <0.001 for the age–sex interaction (Figure 2, Table S4).

Discussion
This large-scale nationwide study of >1 million cases provides a comprehensive update of the epidemiology of dementia in southern Europe. Our findings highlighted that records of dementia diagnoses routinely collected in primary care and registered in SIDIAP are accurate enough to be used for research purposes. Moreover, we provided a detailed update about crude and standardized prevalence and incidence rates, which may help to improve policies related to dementia not only in primary-care settings but also in secondary care.

Validation of dementia diagnoses
We found a 91% PPV of diagnoses of dementia recorded in SIDIAP. Sensitivity analyses showed that in the worst scenario, the PPV would be 77.8%. Our PPV estimate was slightly higher than values observed in previous studies that assessed the quality of routinely collected data on dementia in primary-care services for research purposes.10,24,25 When routinely collected electronic health records are applied to research, avoiding false-positive diagnoses could be more important than avoiding false negatives. In longitudinal studies, for example, false positives can dilute observed effects and reduce statistical power.26 Our results highlighted that false positives on dementia cases are scarce in SIDIAP and that patients having a record in SIDIAP of a diagnosis of dementia are very likely to have the disease. Therefore, the SIDIAP database is valid for epidemiological research on dementia.

Incidence and prevalence
We estimated an age- and sex-standardized incidence of 8.6/1,000 person-years (95% CI 8.0–9.3), similar to the adjusted incidence estimated by the NEDICES study on the Spanish population aged ≥65 years.27 Other studies conducted in Spain have reported disparate estimates of dementia incidence.28,29 However, differences in study populations and methodologies limit comparability with our findings. When comparing incidence of dementia according to age-group, our estimations were similar to those reported by Bermejo-Pareja et al27 and Lobo et al 28 in all age-groups except the oldest old (aged at least 85 years), in which our values were lower than the face-to-face studies cited. This disparity might be partially due to some level of underregistration in SIDIAP, mainly concentrated in the oldest-old patients, in line with previous studies.30 Some general practitioners may consider memory difficulties part of the normal aging process, rather than a disability that requires specialist care and support,31 while others might be reluctant to use dementia codes in this age-group because they consider the diagnosis and treatment of dementia useless.8,31

We estimated the age- and sex-standardized prevalence of dementia as 5.1% (95% CI 4.5%–5.7%), which overlapped with the standardized estimations reported by the most recent face-to-face studies in the Spanish population at least 65 years old.4,5 Previous face-to-face studies – mostly conducted before 2010 – reported crude prevalence estimates, ranging from 5.5% to 14.9% in Spanish people aged ≥65
Figure 2 Incidence rate (A) and prevalence (B) of dementia.

Note: According to sex (green line, women; blue line, men; red line, overall population) by age-group in Catalan population aged at least 65 years.
years.32–35 At the European level, age- and sex-standardized prevalence of dementia was estimated at 6.4% by a collaborative study of population-based cohorts conducted in the 1990s,36 7.3% by a meta-analysis that integrated studies conducted from 1980 until 2004,37 and 7.1% based on a meta-analysis on data obtained mainly during the 1990s and 2000s.38 More recent national estimates have been 6.5% in the UK,39 3.65% in Portugal,40 or 5.0% in Greece.41 Our prevalence estimation fell in the lower range of published results from the 1990s and early 2000s in face-to-face studies in Spain and in the European population, and were in line with the most recent estimations. The prevalence of dementia has been reported to be decreasing in high-income countries,42 the USA,43 the UK,39 and Spain.44 However, comparisons between studies are difficult to make, because of methodological differences. Therefore, it is plausible that our 2016 estimates reflect a reduction in dementia cases since the 1990s or 2000s, but we cannot reject other explanations. Population characteristics could be a factor. For example, most of the population in Catalonia is bilingual in Catalan and Spanish. Bilingualism may contribute to cognitive reserve and protect against the onset of dementia,45 and could have affected our estimates. SIDIAP does not provide data on languages spoken by patients.

### Electronic health records

In a comparison with other studies based on electronic health records, our findings provided new insights about the epidemiology of dementia. Our results were similar to those reported by a study that used diagnoses and drug-prescription data from primary-care and pharmacy electronic databases to estimate unadjusted prevalence as 5.91% (95% CI 5.85%–5.95%) in persons at least 65 years old living in Madrid in 2011.6 However, our estimates were higher than previous studies in other European populations. A Danish study estimated the prevalence of dementia at 3.8% using electronic health records from secondary-care settings.46 Another study, by Perera et al, compiled data from six electronic health-record systems, including both primary and secondary care from different European countries, to estimate prevalence and incidence rates of dementia.7 They reported lower incidence and prevalence estimates in all age-groups than the ones we observed. Such differences remained for estimates restricted to data from primary-care settings.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Cases</th>
<th>Population</th>
<th>Crude prevalence (95% CI)</th>
<th>Standardized prevalence (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole population</td>
<td>63,117</td>
<td>1,048,956</td>
<td>6.0 (6.0–6.1)</td>
<td>5.1 (4.5–5.7)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Women</td>
<td>43,995</td>
<td>599,942</td>
<td>7.3 (7.3–7.4)</td>
<td>5.9 (5.5–6.3)</td>
</tr>
<tr>
<td>Men</td>
<td>19,122</td>
<td>449,014</td>
<td>4.3 (4.2–4.3)</td>
<td>4.2 (3.8–4.7)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
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</tr>
<tr>
<td>65–69 years</td>
<td>2,151</td>
<td>282,815</td>
<td>0.8 (0.7–0.8)</td>
<td>0.8 (0.7-0.8)</td>
</tr>
<tr>
<td>70–74 years</td>
<td>4,812</td>
<td>242,888</td>
<td>2.0 (1.9–2.0)</td>
<td>2.0 (1.9-2.1)</td>
</tr>
<tr>
<td>75–79 years</td>
<td>8,750</td>
<td>179,329</td>
<td>4.9 (4.8–5.0)</td>
<td>4.8 (4.6-5.0)</td>
</tr>
<tr>
<td>80–84 years</td>
<td>16,906</td>
<td>171,494</td>
<td>9.9 (9.7–10.0)</td>
<td>9.5 (9.2–9.8)</td>
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<tr>
<td>85–89 years</td>
<td>17,884</td>
<td>110,530</td>
<td>16.2 (16.0–16.4)</td>
<td>15.4 (14.9–15.8)</td>
</tr>
<tr>
<td>≥90 years</td>
<td>12,614</td>
<td>61,900</td>
<td>20.4 (20.1–20.7)</td>
<td>18.5 (17.8–19.2)</td>
</tr>
</tbody>
</table>

Note: *Age-and sex-standardized; +age-standardized; +sex-standardized.

<table>
<thead>
<tr>
<th>Table 2 Description of the characteristics of the primary care settings in Catalonia (Spain) in relation to dementia assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dementia assessment</td>
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<tr>
<td>------------------</td>
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<tr>
<td>Patients at home-care program</td>
</tr>
<tr>
<td>Institutionalized patients</td>
</tr>
<tr>
<td>Cognitive abilities</td>
</tr>
<tr>
<td>Persons assessed</td>
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<tr>
<td>Persons impaired</td>
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<tr>
<td>Functional ability and independence</td>
</tr>
<tr>
<td>Persons assessed</td>
</tr>
<tr>
<td>Persons impaired</td>
</tr>
</tbody>
</table>
which contained fewer dementia cases than SIDIAP. These
differences might be partially explained by methodological
issues, demographic aspects, and characteristics of primary-
care settings. Our methodology applied a mixed definition of
dementia that included not only diagnosis but also prescrip-
tion or billing of antidementia drugs. This broader definition
might capture more dementia cases than that used by Perera
et al, who identified cases using only diagnostic codes or
free text.7 Demographic aspects might also contribute to
explaining differences between primary-care databases from
different countries. Life expectancy in Spain is the longest
in the EU (83.3 years),47 and the sex gap in life expectancy
 favors women to a higher extent than in other countries,
such as Denmark, the Netherlands, or the UK.47 Since
dementia prevalence is higher in women and increases with
age, demographic characteristics of the population might
facilitate a higher number of dementia cases in Spain than in
other European countries. Primary-care characteristics might
also contribute to explaining disparities between studies on
dementia epidemiology based on electronic health records
from primary care. Catalan primary-care settings from which
SIDIAP obtained data might be highly sensitive in diagnosing
dementia cases. On one hand, cognitive tests are administered
widely to identify dementia cases in the Catalan primary-care
system: in SIDIAP, >22% of patients with no dementia code
in their electronic health history had taken a cognitive test.
Patients with memory complaints reported by themselves,
their relatives, or general practitioners are asked to take a
cognitive test. Patients included in specific programs for home
 care or institutionalized due to chronic complex disease may
also be asked to complete a cognitive test, even if they have
no memory or cognitive complaints. The huge number of
cognitive tests administered in Catalan primary care might
facilitate the identification of new dementia cases.14 On the
other hand, we found that most patients with a dementia code
in SIDIAP had been diagnosed by a specialist or prescribed
antidementia drugs by specialists. These findings suggest a
good coordination between primary and secondary settings
provided by the Catalan Health Institute, strengthened by
such initiatives as the Computerized Support System for the
Diagnosis of Dementia in Primary Care (SISDDAP
[Catalan acronym]), an asynchronous telemedicine program
involving both primary- and specialized-care professionals
that establishes protocols for the screening and diagnosis of
dementia.48 Appropriate communication and coordination
between primary and secondary care might facilitate the
identification of new dementia cases and the recording of
diagnoses in the electronic health record. Our findings are
in line with previous literature reporting that settings with
active dementia-diagnosis centers are likely to see a higher
proportion of community cases in health care databases.7 Our
findings also suggested that the high level of underdiagnosis
of dementia reported in several primary-care systems31,49
might not be true for other primary-care settings. General
practitioner concern and training, as well as programs and
policies designed to better diagnose dementia cases, might
help to reduce underdiagnosis in primary care. Therefore,
databases containing routinely collected data from primary
care might be a powerful tool to study dementia epidemiology
if data have been recorded in a setting with active manage-
ment of dementia cases and validated as sufficiently accurate
for research purposes.

Limitations and strengths
We acknowledge several limitations. First, the PPV could have
been overestimated, because the validation study was con-
strained to general practitioners from the AGICAP network,
who are regularly involved in clinical trials and thus could
be more prone to register diagnoses accurately in electronic
medical records. Second, as not all dementia diagnoses were
evaluated by general practitioners, we cannot discard a poten-
tial bias that might have resulted in an overestimation of the
PPV. Therefore, we replicated the PPV estimate considering
the worst-case scenario, in which data from both evaluated
and unevaluated dementia diagnoses were used. This worst-
 case scenario PPV estimate would indicate the minimum
value of the PPV, ie, if bias had occurred and the PPV value
had been overestimated, the PPV would not be lower than
the worst-case scenario estimate. Third, the validation study
did not provide sensitivity estimates of dementia diagnoses
recorded in SIDIAP: it was cost-prohibitive to search for cases
in persons with no recorded dementia diagnosis in SIDIAP.
However, sensitivity has been reported to be less crucial
than PPV in evaluating the accuracy of routinely collected
health data, because the effects of false negatives would be
diluted among the large control population.19 Moreover, our
prevalence estimates were quite similar to those reported
by clinical studies in Spain during the last decade, and a
decreasing trend in prevalence figures has been observed in
high-income countries.42 All this suggests that the recording
of dementia diagnoses in SIDIAP is satisfactory. Fourth, we
did not use free text to improve identification of persons with
dementia. However, we used a mixed definition of dementia
cases that included diagnosis and prescription or billing codes
involving not only data from the general practitioner but also
from the pharmacy-invoicing database. Using two different
data sources minimized the possible effect of underrecording of dementia diagnoses in SIDIAP. Finally, a lower education level has been associated with a greater risk of dementia.10 We could not stratify the results according to literacy, since this information is unavailable in SIDIAP.

Our study has several strengths. First, it included about 10,000 incident cases in 1 year and 63,000 prevalent cases, while most epidemiological studies on dementia conducted in Western Europe had smaller samples.1 Second, our study did not depend on participants' response rate, and thus was not affected by selection bias due to lack of response, which can be common among people with dementia due to reluctance of relatives to participate or difficulties in completing the questionnaires.1 Finally, this was a nationwide study that included >1 million people in Catalonia, a 32,000 km² region of southern Europe. Therefore, this study provides better representation of the Spanish population than previous studies conducted in a single city5,34,44,51 or a limited area. The nationwide approach may facilitate the design and implementation of new dementia policies in national health systems.

Conclusion

Dementia diagnoses recorded in the SIDIAP database are valid to be used for research purposes. Age- and sex-standardized prevalence and incidence rates of dementia in 2016 were higher for women and the oldest-old population. Our figures were in line with the most recent studies conducted in Spain and higher than those provided by other primary-care databases from other European countries. These findings may be helpful to plan dementia policies not only in primary-care settings but also in secondary care and in the overall public health system.

Acknowledgments

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Disclosure

The authors report no conflicts of interest in this work.

References


19. Alvarez Solar M, At DAR, Gurpegui B. Capacidad funcional de pacientes mayores de 65 años, según el Índice de Katz [Functional ability of patients aged 65 years or older according to the Katz index]. Aten Primaria. 1992;10:812–815.


Supplementary materials

Question: at this point, what is the basis for a diagnosis of dementia?

Answer 1- The diagnosis was made by a hospital specialist
  • Indicate the subtype of dementia
  • Indicate the severity of dementia

Answer 2- The diagnosis was based on cognitive and functional tests
  • Specify the test(s) and the score(s)
  • Indicate the subtype of dementia
  • Indicate the severity of dementia
  • Are the DSM-IV or CIE-10 diagnostic criteria fulfilled? (Yes/No)

Answer 3- The diagnosis was based on clinical opinion
  • Symptoms were observed by a general practitioner, care giver or patient relative.
  • Indicate the subtype of dementia
  • Indicate the severity of dementia
  • Are the DSM-IV or CIE-10 diagnosis criteria fulfilled? (Yes/No/Not sure)

Answer 4- The diagnosis is null (evolved or incorrect diagnosis)

Answer 5- Uncertain due to lack of information

Figure S1 Summary of questionnaire for the validation of dementia diagnosis.

Abbreviations: CIE-10, Código Internacional de Enfermedades (Spanish version of the ICD); DSM, Diagnostic and Statistical Manual of Mental Disorders.

Table S1 Characteristics of study population to estimate incidence rate of dementia

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Patients with dementia, n (%), x [SD]</th>
<th>Dementia-free patients, n (%), x [SD]</th>
<th>Study population, n (%), x [SD]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>82.9 [7.0]</td>
<td>75.6 [7.9]</td>
<td>75.7 [7.9]</td>
</tr>
<tr>
<td>Women</td>
<td>6,218 (64.8)</td>
<td>575,442 (56.1)</td>
<td>581,660 (56.2)</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>1,150 (12.0)</td>
<td>100,134 (9.8)</td>
<td>101,284 (9.8)</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>1,854 (19.3)</td>
<td>92,722 (9.0)</td>
<td>94,576 (9.1)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>6,972 (72.7)</td>
<td>633,792 (63.8)</td>
<td>660,764 (63.8)</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>5,076 (52.9)</td>
<td>549,597 (53.6)</td>
<td>554,673 (53.6)</td>
</tr>
<tr>
<td>Depression</td>
<td>2,676 (27.9)</td>
<td>163,728 (16.0)</td>
<td>166,404 (16.1)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>2,868 (29.9)</td>
<td>211,599 (24.5)</td>
<td>254,467 (24.6)</td>
</tr>
<tr>
<td>Anemia</td>
<td>2,392 (24.9)</td>
<td>155,196 (15.1)</td>
<td>157,588 (15.2)</td>
</tr>
<tr>
<td>Hyperthyroidism</td>
<td>57 (0.6)</td>
<td>5,072 (0.5)</td>
<td>5,129 (0.5)</td>
</tr>
<tr>
<td>Cancer</td>
<td>1,996 (20.8)</td>
<td>193,459 (18.9)</td>
<td>195,455 (18.9)</td>
</tr>
</tbody>
</table>

Table S2 Crude incidence rates of dementia (per 1,000 person-years) in people aged ≥65 years in Catalonia (Spain) in 2016, stratified by sex and age

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age group (years)</th>
<th>Cases</th>
<th>Person/years</th>
<th>Incidence (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>65–69</td>
<td>174</td>
<td>149,440</td>
<td>1.2 (1.0–1.4)</td>
</tr>
<tr>
<td></td>
<td>70–74</td>
<td>522</td>
<td>129,528</td>
<td>4.0 (3.7–4.4)</td>
</tr>
<tr>
<td></td>
<td>75–79</td>
<td>929</td>
<td>95,991</td>
<td>9.7 (9.1–10.3)</td>
</tr>
<tr>
<td></td>
<td>80–84</td>
<td>1,739</td>
<td>93,356</td>
<td>18.6 (17.8–19.5)</td>
</tr>
<tr>
<td></td>
<td>85–89</td>
<td>1,667</td>
<td>61,408</td>
<td>27.2 (25.9–28.5)</td>
</tr>
<tr>
<td></td>
<td>≥90</td>
<td>1,187</td>
<td>38,113</td>
<td>31.1 (29.4–33.0)</td>
</tr>
<tr>
<td>Men</td>
<td>65–69</td>
<td>156</td>
<td>133,459</td>
<td>1.2 (1.0–1.4)</td>
</tr>
<tr>
<td></td>
<td>70–74</td>
<td>398</td>
<td>111,178</td>
<td>3.6 (3.2–4.0)</td>
</tr>
<tr>
<td></td>
<td>75–79</td>
<td>645</td>
<td>77,711</td>
<td>8.3 (7.7–9.0)</td>
</tr>
<tr>
<td></td>
<td>80–84</td>
<td>928</td>
<td>65,940</td>
<td>14.1 (13.2–15.0)</td>
</tr>
<tr>
<td></td>
<td>85–89</td>
<td>823</td>
<td>36,223</td>
<td>22.7 (21.2–24.3)</td>
</tr>
<tr>
<td></td>
<td>≥90</td>
<td>428</td>
<td>16,430</td>
<td>26.1 (23.6–28.6)</td>
</tr>
</tbody>
</table>
### Table S3 Characteristics of study population to estimate dementia prevalence that includes persons aged ≥65 years registered in SIDIAP on December 31, 2016

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Patients with dementia, n (%), x [SD]</th>
<th>Dementia-free patients, n (%), x [SD]</th>
<th>Study population, n (%), x [SD]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>83.7 [6.9]</td>
<td>75.4 [7.7]</td>
<td>75.9 [7.9]</td>
</tr>
<tr>
<td>Women</td>
<td>43,995 (69.7)</td>
<td>555,947 (56.4)</td>
<td>599,942 (57.2)</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>7,122 (11.3)</td>
<td>93,749 (9.5)</td>
<td>100,871 (9.6)</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>12,281 (19.5)</td>
<td>85,878 (8.7)</td>
<td>98,159 (9.4)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>44,880 (71.1)</td>
<td>628,783 (63.8)</td>
<td>673,663 (64.2)</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>34,324 (54.4)</td>
<td>533,427 (54.1)</td>
<td>567,751 (54.1)</td>
</tr>
<tr>
<td>Depression</td>
<td>18,389 (29.1)</td>
<td>157,376 (15.9)</td>
<td>175,765 (16.8)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>18,361 (29.1)</td>
<td>239,853 (24.3)</td>
<td>258,214 (24.6)</td>
</tr>
<tr>
<td>Anemia</td>
<td>17,125 (27.1)</td>
<td>143,399 (14.6)</td>
<td>160,524 (15.3)</td>
</tr>
<tr>
<td>Hyperthyroidism</td>
<td>412 (0.7)</td>
<td>4,868 (0.5)</td>
<td>5,280 (0.5)</td>
</tr>
<tr>
<td>Cancer</td>
<td>11,914 (18.9)</td>
<td>179,050 (18.2)</td>
<td>190,964 (18.2)</td>
</tr>
</tbody>
</table>

**Abbreviation:** SIDIAP, System for the Development of Research in Primary Care.

### Table S4 Crude prevalence of dementia in people aged ≥65 years in Catalonia (Spain) in 2016, stratified by sex and age

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age-group (years)</th>
<th>Cases</th>
<th>Population</th>
<th>Prevalence (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>65–69</td>
<td>1,180</td>
<td>149,811</td>
<td>0.8 (0.7–0.8)</td>
</tr>
<tr>
<td></td>
<td>70–74</td>
<td>2,767</td>
<td>131,252</td>
<td>2.1 (2.0–2.2)</td>
</tr>
<tr>
<td></td>
<td>75–79</td>
<td>5,446</td>
<td>100,054</td>
<td>5.4 (5.3–5.6)</td>
</tr>
<tr>
<td></td>
<td>80–84</td>
<td>11,493</td>
<td>102,434</td>
<td>11.2 (11.0–11.4)</td>
</tr>
<tr>
<td></td>
<td>85–89</td>
<td>12,923</td>
<td>71,533</td>
<td>18.1 (17.8–18.3)</td>
</tr>
<tr>
<td></td>
<td>≥90</td>
<td>10,186</td>
<td>44,858</td>
<td>22.7 (22.3–23.1)</td>
</tr>
<tr>
<td>Men</td>
<td>65–69</td>
<td>971</td>
<td>133,004</td>
<td>0.7 (0.7–0.8)</td>
</tr>
<tr>
<td></td>
<td>70–74</td>
<td>2,045</td>
<td>111,636</td>
<td>1.8 (1.8–1.9)</td>
</tr>
<tr>
<td></td>
<td>75–79</td>
<td>3,304</td>
<td>79,275</td>
<td>4.2 (4.0–4.3)</td>
</tr>
<tr>
<td></td>
<td>80–84</td>
<td>5,413</td>
<td>69,060</td>
<td>7.8 (7.6–8.0)</td>
</tr>
<tr>
<td></td>
<td>85–89</td>
<td>4,961</td>
<td>38,997</td>
<td>12.7 (12.4–13.1)</td>
</tr>
<tr>
<td></td>
<td>≥90</td>
<td>2,428</td>
<td>17,042</td>
<td>14.2 (13.7–14.8)</td>
</tr>
</tbody>
</table>