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Prevalence of Dementia in the United States: The Aging, Demographics, and Memory Study

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Key Words
Dementia · Aging · Epidemiology · Population-based research

Abstract
Aim: To estimate the prevalence of Alzheimer's disease (AD) and other dementias in the USA using a nationally representative sample. ***Methods:*** The Aging, Demographics, and Memory Study sample was composed of 856 individuals aged 71 years and older from the nationally representative Health and Retirement Study (HRS) who were evaluated for dementia using a comprehensive in-home assessment. An expert consensus panel used this information to assign a diagnosis of normal cognition, cognitive impairment but not demented, or dementia (and dementia subtype). Using sampling weights derived from the HRS, we estimated the national prevalence of dementia, AD and vascular dementia by age and gender. ***Results:*** The prevalence of dementia among individuals aged 71 and older was 13.9%, comprising about 3.4 million individuals in the USA in 2002. The corresponding values for AD were 9.7% and 2.4 million individuals. Dementia prevalence increased with age, from 5.0% of those aged 71–79 years to 37.4% of those aged 90 and older. ***Conclusions:*** Dementia prevalence estimates from this first nationally representative population-based study of dementia in the USA to include subjects from all regions of the country can provide essential information for effective planning for the impending healthcare needs of the large and increasing number of individuals at risk for dementia as our population ages.

Background

The elderly population (those aged 65 years or older) in the USA is expected to double from approximately 35 million today to more than 70 million by 2030 [1]. With this rapid growth in the number of older Americans, prevention and treatment of chronic diseases of aging will take on growing importance. Dementia is a disease of particular concern because the decline in memory and other cognitive functions that characterizes this condition also leads to a loss of independent function that has a wide-ranging impact on individuals, families and healthcare systems. Accurate national estimates of the current and future prevalence of dementia are essential for effective planning for the long-term care and medical costs that will fall to the Social Security, Medicare and

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other insurance programs for elderly adults in the USA. To date, five important reports have estimated the prevalence of dementia or Alzheimer's disease (AD) in the USA [2–6], all employing extrapolations from a few US communities or from European and Canadian studies. However, studies of other medical conditions, such as stroke, hypertension and cancer, suggest substantial regional variation in the occurrence of these conditions throughout the USA [7, 8]. Similar regional variability may occur for dementia as well. In an attempt to directly determine the dementia prevalence rate in the USA, we conducted the Aging, Demographics, and Memory Study (ADAMS), the first population-based study of dementia to include individuals from all regions of the country.

Methods

Sample

The ADAMS sample was drawn from the larger Health and Retirement Study (HRS), an ongoing nationally representative cohort study of individuals born prior to 1954, designed to investigate the health, social and economic implications of the aging of the American population [9–11]. The HRS began in 1992, and the current sample includes approximately 22,000 individuals. HRS data include measures of cognition that enable a cost-efficient stratified sample design for a study of dementia.

The ADAMS sample began with a stratified random subsample of 1,770 individuals ≥70 years old at the time of selection from the HRS sample. ADAMS participants lived in 42 states distributed throughout all census regions of the USA. The ADAMS sample was composed of 5 cognitive strata that were defined based on participants' performance on self- or proxy-reported cognitive screening measures [12] in their most recent HRS interview (either 2000 or 2002). The 3 highest cognitive strata were further stratified by age (age 70–79 vs. 80 or older) and sex in order to ensure adequate numbers in each of these subgroups. Full details of the ADAMS sample design and selection procedures are described elsewhere [13, 14]. The ADAMS assessments occurred between July 2001 and December 2003, on average a year or more after the HRS interview. Thus, participants were ≥71 years old at the time of assessment.

A total of 856 individuals, 56% of the nondeceased target sample, participated in all phases of the dementia assessment. Reasons for nonparticipation included: failure to contact (4%), refusal (32%) and other reasons (8%, e.g. lack of proxy, illness). A major concern in the ADAMS, as in similar population-based studies, is the potential for selective nonparticipation. However, because the ADAMS sample was derived from the HRS, a wide range of health and social information was available to assess and correct for potential selection bias in our sample. Using logistic regression, the probability that a sample subject participated in the ADAMS assessment was modeled as a function of covariates including: age, gender, education, marital status, HRS cognition scores, nursing home residency and indicators of prior or existing major health conditions such as cancer, heart disease, stroke, diabetes or psychiatric disorders. Among persons who were able to complete the previous HRS interview without the aid of a proxy (self-reporters), male gender and a previous diagnosis of cancer or stroke were associated with higher rates of ADAMS participation. For subjects who required assistance of a caregiver or other proxy to complete the previous HRS interview, higher ADAMS participation rates were observed for women, nursing home residents and subjects with generally lower cognitive function status. The results of this response propensity analysis were used to develop nonresponse adjustments to the ADAMS sample selection weights [15]. Population sample weights were then constructed to take into account the probabilities of selection in the stratified sample design and to adjust for differential nonparticipation in the ADAMS [13].

All analyses were conducted in SAS V9.1.3 using the special Survey procedures that account for the influence of this weighting and other complex sample design features on the standard errors and confidence intervals of sample estimates, as well as the values of test statistics. The ADAMS data are publicly available and can be obtained from the HRS website [16].

All study procedures were approved by the Institutional Review Boards at Duke University Medical Center and the University of Michigan, and informed consent was obtained from study participants or their surrogates.

Dementia Assessment and Diagnosis

All participants were assessed for dementia in person in their residence by a nurse and neuropsychology technician. The full details of this assessment and diagnostic procedures have been previously described [14]. Briefly, the following information about the respondent was collected from a knowledgeable informant: (1) a detailed chronological history of cognitive and functional symptoms, (2) medical history, (3) current medications, (4) current neuropsychiatric symptoms, (5) measures of severity of cognitive and functional impairment, and (6) family history of memory problems. During the assessment, the respondent completed: (1) a battery of neuropsychological measures; (2) a self-report depression measure; (3) a standardized neurological examination; (4) a blood pressure measurement; (5) collection of buccal DNA samples for apolipoprotein E (APOE) genotyping, and (6) a 7-min videotaped segment covering portions of the cognitive status and neurological examinations. The neuropsychological battery has been described elsewhere [14] and included measures of orientation, verbal and visual immediate and delayed memory, language, attention, executive function, praxis, reading ability and general intellect. Medical record releases were also sought to obtain relevant prior neuroimaging and laboratory results from the respondents' physicians.

All information collected during the in-home assessment was reviewed, and preliminary research diagnoses regarding cognitive status were assigned in case conferences at Duke University that were attended by a geropsychiatrist (D.C.S.), neurologist (J.R.B.), neuropsychologist (G.G.P.), a cognitive neuroscientist (B.L.P.), and the nurses and neuropsychology technicians. Relevant medical records were reviewed as part of the diagnostic process. Final diagnoses were assigned by a consensus expert panel made up of neuropsychologists, neurologists, geropsychiatrists and internists. The consensus panel reviewed each case and assigned a diagnosis in two stages, first without the medical records and then with the medical records. All individuals involved in the

Table 1. Characteristics of the ADAMS sample

	All	All demented	AD	VaD	Dementia, undetermined etiology	Nondemented
Overall	856 (100)	308 (100)	229 (100)	48 (100)	23 (100)	548 (100)
Age						
71–79 years	355 (58.6)	62 (20.9)	37 (14.0)	14 (23.7)	8 (64.2)	293 (64.7)
80–89 years	366 (33.7)	158 (58.6)	119 (62.7)	25 (56.8)	10 (29.1)	208 (29.7)
≥90 years	135 (7.7)	88 (20.5)	73 (23.3)	9 (19.5)	5 (6.7)	47 (5.6)
Sex						
Male	355 (39.3)	95 (31.5)	59 (28.5)	20 (37.9)	13 (43.0)	260 (40.6)
Female	501 (60.7)	213 (68.5)	170 (71.5)	28 (62.1)	10 (57.0)	288 (59.4)
Education						
0–8 years	291 (17.4)	125 (33.5)	93 (32.2)	18 (33.8)	12 (48.0)	166 (14.7)
9–11 years	144 (16.1)	53 (15.3)	39 (16.1)	7 (9.9)	4 (17.4)	91 (16.3)
12 years	203 (29.4)	71 (27.2)	55 (29.2)	10 (32.2)	4 (6.4)	132 (29.8)
>12 years	218 (37.1)	59 (24.0)	42 (22.5)	13 (24.1)	3 (28.2)	159 (39.2)
Race/ethnicity						
Non-Hispanic White	613 (87.1)	218 (83.4)	162 (82.1)	36 (87.3)	15 (86.4)	395 (87.7)
Non-Hispanic Black	159 (7.6)	67 (12.4)	49 (12.9)	9 (10.5)	7 (12.3)	92 (6.9)
Hispanic	84 (5.2)	23 (4.2)	18 (5.0)	3 (2.2)	1 (1.3)	61 (5.4)

Numbers are unweighted, percentages (in parentheses) are weighted and calculated within columns.

clinical assessments or diagnosis of ADAMS participants were blind to the participants' HRS cognitive screening scores.

Diagnoses fell within the three general categories: normal cognitive function, cognitively impaired but not demented (CIND), and dementia. Dementia diagnosis was based on guidelines from DSM-III-R [17] and DSM-IV [18] criteria; however, if the two sets of criteria resulted in discrepant outcomes, the final diagnosis was based on the clinical judgment of the consensus panel. Currently accepted diagnostic criteria for subtypes of dementia were used [19–21, 27]. DSM criteria for dementia require memory impairment; however, some subtypes of dementia do not present with prominent memory problems. To account for this, the diagnostic process was anchored by the criteria, but the consensus panel used clinical judgments to assign the final diagnosis. To reflect that dementia is often the consequence of more than one pathological process, we assigned a primary and secondary diagnosis denoting these multiple etiologies. Our assessment and diagnostic procedures have been validated against neuropathological diagnoses [22].

Analyses

Using the ADAMS population weights described above, we estimated the national prevalence of dementia, AD and vascular dementia (VaD) in 2002 for all individuals aged 71 and older, stratified by 9- or 10-year age categories. We then re-ran the analyses grouping the 'dementia, undetermined etiology' as AD because this diagnostic category includes AD in the differential diagnosis and postmortem examinations have shown that the majority of individuals with this clinical diagnosis have neuropathology consistent with definite AD [22].

We then estimated the total number of individuals aged 71 and older in the USA in 2002 with dementia, AD and VaD using the ADAMS population weights. The total size of the age 71 and older population for 2002 using the ADAMS population weights matched closely the population estimates from the USA Census Bureau and Current Population Survey [23, 24].

To examine purported predictors of dementia reported by other studies, we used logistic regression to estimate the likelihood of dementia and AD first as a function of age and each of the following variables individually: years of education, gender, race and APOE genotype. We then ran models that included age, education and gender, and sequentially added the other variables to identify predictors of the outcome (dementia, AD). In these models, race was dichotomized as African American or Caucasian. Other ethnic and racial groups were not included in these analyses due to the small sample sizes.

Results

Prevalence of Dementia, AD and VaD

Table 1 provides sample characteristics for the 856 ADAMS participants based on dementia status. The sample is well distributed across the range of age and education levels with a significant number of individuals aged 90 years or older and also a large percentage with 8 or fewer years of education.

Table 2. National prevalence of dementia, AD and VaD, by age categories

Age	All dementia			AD			VaD		
	combined	male	female	combined	male	female	combined	male	female
71–79 years	4.97 (2.61–7.32)	5.25 (1.25–9.25)	4.76 (1.82–7.70)	2.32 (1.26–3.37)	2.30 (0.80–3.81)	2.33 (0.95–3.70)	0.98 (0.07–1.89)	1.27 (0.00–3.19)	0.76 (0.18–1.35)
80–89 years	24.19 (19.28–29.11)	17.68 (11.66–23.70)	27.84 (20.41–35.28)	18.10 (13.47–22.74)	12.33 (5.82–18.84)	21.34 (14.44–28.24)	4.09 (1.52–6.67)	3.58 (1.37–5.79)	4.38 (0.71–8.05)
≥90 years	37.36 (25.45–49.27)	44.59 (21.70–67.47)	34.69 (23.36–46.02)	29.70 (18.60–40.80)	33.89 (10.00–57.77)	28.15 (17.61–38.69)	6.19 (2.14–10.23)	8.14 (0.0–16.76)	5.46 (1.49–9.44)
Total	13.93 (11.42–16.44)	11.14 (7.78–14.50)	15.74 (12.39–19.08)	9.74 (7.56–11.91)	7.05 (4.25–9.85)	11.48 (8.50–14.46)	2.43 (1.36–3.50)	2.34 (0.74–3.94)	2.48 (1.11–3.86)

Percentages and 95% confidence intervals (in parentheses) provided.

Table 3. National estimates of the number of individuals with dementia or AD

Age	All dementia	AD
71–79 years	712,000 (375,000–1,050,000)	332,000 (181,000–483,000)
80–89 years	1,996,000 (1,590,000–2,401,000)	1,493,000 (1,111,000–1,875,000)
≥90 years	699,000 (476,000–922,000)	556,000 (348,000–763,000)
Total	3,407,000 (2,793,000–4,021,000)	2,381,000 (1,849,000–2,913,000)

95% CI in parentheses.

Table 2 shows the overall national prevalence estimates for AD, VaD and all dementia, and additionally stratified by gender and 9- or 10-year age ranges. As expected, the national prevalence of AD, VaD and all dementia increased with age, reaching 37.4% dementia prevalence among individuals aged 90 and older.

Overall, AD accounted for approximately 69.9% of all dementia, while VaD accounted for 17.4%. Other types of dementia such as 'dementia, undetermined etiology', Parkinson's dementia, normal-pressure hydrocephalus, frontal lobe dementia, alcoholic dementia, traumatic brain injury and Lewy body dementia accounted for the remaining 12.7% of cases. With increasing age, AD accounted for progressively more of the dementia cases so that in the age 90+ group, AD accounted for 79.5% of the dementia cases compared to 46.7% among those aged 71–79 years.

When those diagnosed as having 'dementia, undetermined etiology' (n = 23) were categorized as AD, the overall prevalence of AD increased to 11.1% (95% confidence interval, CI = 8.86–13.40%), with corresponding values of 8.6% (6.01–11.13%) for males and 12.8% (9.50–16.07%) for females.

The estimated numbers of individuals nationwide aged 71 years and older with dementia and AD are reported in table 3. The corresponding estimate for the overall number of cases of VaD is 594,000 (332,000–856,000).

Predictors of Dementia or AD

In a series of logistic models that included age and one additional variable (i.e. education, gender, race, or APOE genotype), older age was consistently associated with an increased risk of dementia ($p < 0.0001$). In these trivariate models, more years of education were associated with a lower risk of dementia ($p < 0.0001$). There was no significant difference in dementia risk between males and females ($p = 0.26$). African Americans were at greater risk for dementia ($p = 0.008$). As expected, the presence of one (odds ratio, OR = 2.1; 95% CI = 1.45–3.07) or two APOE ε4 alleles (OR = 7.1; 95% CI = 2.92–17.07) was significantly associated with an increased risk of dementia.

As shown in table 4, in the multivariate models, dementia risk increased with older age, fewer years of education and the presence of at least one APOE ε4 allele. In the presence of these variables, gender and race were not significantly associated with risk of dementia.

In a series of parallel logistic regression models for AD that included age and one additional term, increasing age was consistently associated with AD ($p < 0.0001$). In these models, more years of education were associated with a lower risk of AD ($p = 0.001$), but there was no difference between risk of AD for males and females ($p = 0.14$). African Americans were more likely to have AD than Cau-

Table 4. Logistic regression models for dementia

	Model 1	Model 2	Model 3
Age	1.16 (1.12–1.20)	1.16 (1.12–1.20)	1.17 (1.13–1.22)
Education	0.90 (0.87–0.94)	0.92 (0.88–0.97)	0.91 (0.87–0.96)
Sex[a]	1.26 (0.88–1.80)	1.22 (0.84–1.76)	1.27 (0.87–1.84)
Race[b]		1.66 (0.94–2.94)	1.38 (0.78–2.45)
Any APOE ε4[c]			2.56 (1.71–3.82)
Wald χ^2		3.07 (1)	21.12 (1)
p value		0.08	<0.001

Results are OR, with 95% CI in parentheses. Wald χ^2 compares the fit of the model to the prior model. Significant p values indicate a significant improvement in model fit.

[a] Male = 0, Female = 1.

[b] Caucasian = 0, African American = 1.

[c] Any APOE ε4 = 1.

Table 5. Logistic regression models for AD

	Model 1	Model 2	Model 3
Age	1.18 (1.14–1.22)	1.18 (1.15–1.22)	1.20 (1.16–1.24)
Education	0.90 (0.86–0.95)	0.92 (0.87–0.98)	0.91 (0.86–0.97)
Sex[a]	1.40 (0.89–2.22)	1.27 (0.80–2.02)	1.31 (0.81–2.13)
Race[b]		1.77 (1.01–3.09)	1.50 (0.83–2.70)
Any APOE ε4[c]			2.67 (1.59–4.49)
Wald χ^2		4.00 (1)	13.81 (1)
p value		0.04	<0.001

Results are OR, with 95% CI in parentheses. Wald χ^2 compares the fit of the model to the prior model. Significant p values indicate a significant improvement in model fit.

[a] Male = 0, Female = 1.

[b] Caucasian = 0, African American = 1.

[c] Any APOE ε4 = 1.

casians (p = 0.002). As expected, the presence of 1 APOE ε4 allele (OR = 1.9; 95% CI = 1.17–3.17) or 2 ε4 alleles (OR = 10.1; 95% CI = 3.83–26.61) was associated with a significantly increased AD risk. As shown in table 5, the results of the multivariate logistic models for AD were similar to those for dementia as a whole.

Discussion

The ADAMS has produced the first prevalence estimates of dementia and AD in a nationally representative sample in the USA to include individuals from all regions of the country. To allow comparison with findings from previous studies using a lower minimum age (i.e. either age 60+ or 65+), we combined the estimates from ADAMS for ages 71 and greater with those from other studies for ages 60–70 [3, 6, 25]. This resulted in an estimated total of 3.8 million individuals with dementia and just over 2.5 million with AD in the USA. The sole previous national estimate of dementia prevalence was 2.9 million, based on a Delphi consensus review of previously published studies in the USA [3]. The four previous national estimates of AD prevalence differed by greater than twofold and ranged from 2.1 million [6] to 4.5 million [5, 26]. The lowest estimate came from a meta-analysis of 18 US and European studies, the highest from the East Boston and Chicago community studies [5, 26]. Variability in prevalence estimates of AD due to geographic factors has been discussed. In addition to the issue of extrapolation from regional samples, one likely source for variation among AD prevalence estimates is the use of different criteria for dementia. Some studies used criteria that do not require evidence of impaired functional performance [27], while most use criteria requiring significant impairment in social or occupational functioning [17, 18]. Another likely source of study variation is the use of different methods to identify the 'border' between cognitive impairment that is not severe enough to meet criteria for dementia. This intermediate state between normal cognitive function and dementia is often referred to as CIND [28] or mild cognitive impairment [29]. Future analyses of ADAMS data, including analyses of longitudinal follow-up assessments of those diagnosed with CIND, will be important to help clarify the border between CIND and dementia in population-based settings.

Comparisons of prevalence estimates across studies are also difficult due to differences in the age brackets reported. However, a general comparison of age-specific prevalence rates from the ADAMS with those from local and regional samples in the USA [30–33] suggests that, as a group, findings from the other studies span the estimates produced in the ADAMS, possibly reflecting its more complete representation of the US population. The

completion of the ADAMS will also facilitate international comparisons of dementia prevalence between other countries and the USA. A comparison with the Canadian population [34] shows that the two countries have similar rates of dementia.

Few predictors of AD and other dementias have been consistently identified across studies. One explanation often cited for these incongruent results is the lack of a sufficient sample size spanning the variable range. On this point, the ADAMS representative sample likely has advantages. Not surprisingly, age was the strongest predictor of both AD and other dementias in the ADAMS. Consistent with several [for a review, see 35, 36], but not all [37] other studies, more years of education were associated with a lower risk of dementia. Several studies have reported that females are at greater risk of AD than males [34, 38, 39]; however, others have reported no such difference [40, 41]. In the ADAMS, women were not at higher risk for AD and other dementias. Results have been discrepant from the few regional studies that have examined race as a predictor for dementia. Some studies reported a higher frequency of AD or dementia among African Americans compared to Caucasians [42, 43], while another reported no such difference [44]. In the ADAMS, African Americans had a higher frequency of dementia and AD, but once education, gender and APOE genotype were controlled, the OR was still elevated, but no longer statistically significant. These findings were similar to those from two other studies [45, 46]. Consistent with many other studies [47], we found that the APOE $\varepsilon 4$ allele was associated with an increased risk of AD and dementia in general.

This study has several strengths: a representative, directly assessed sample of the US population aged 71 and older; the inclusion of large numbers of individuals with few years of education; a sizeable sample over the age of 90, and the inclusion of long-term care residents. All of these groups have a high prevalence of dementia. In addition, employing a single, experienced assessment team, successfully used in other population studies, and one common expert case review panel likely minimized diagnostic variability.

Some limitations also exist. The ADAMS participation rate was lower than hoped for but comparable to other population studies of this age group, such as the Cardiovascular Health Study (participation rate of 57.3% [48]) and the Canadian Study of Health and Aging (68.5% [34]). Both studies have made major scientific contributions to our understanding of health and memory in late life. Nonparticipation in all such studies could result in selection bias. The ADAMS has addressed potential nonresponse bias using detailed archived information from prior interviews, although models based on measures collected 6–18 months prior to the ADAMS assessment may not fully capture selection bias. However, given the range of available measures, it is likely that the response propensity models and the associated weighting adjustments do capture the major factors that could contribute to any significant selection bias in population estimates based on the ADAMS data. We also note that the lack of neuroimaging and other medical tests for all participants may have influenced the accuracy with which non-AD dementias were identified. However, for the 39% of individuals with dementia for whom neuroimaging results were available, in no instance was a solely non-VaD diagnosis that was assigned prior to review of neuroimaging subsequently changed to a solely VaD diagnosis after review of these records. Finally, our supplemental analyses grouping those with 'dementia, undetermined etiology' with the AD group may somewhat overestimate the prevalence of AD. Our previous research [22] justifying this analysis included only Caucasian subjects. Although 16 of the 23 individuals with 'dementia, undetermined etiology' in the ADAMS were Caucasian, it is not clear whether these findings would generalize to the minority of African Americans with this diagnosis in the ADAMS.

As the elderly US population grows, the number of individuals with dementia will also increase, making planning for the long-term care needs of these individuals increasingly important. The value of the ADAMS, the first study of dementia in a nationally representative sample in the USA, extends beyond just estimating the prevalence of dementia to being able to address many of the key questions in preparing for the care of the demented and their families. These prevalence estimates provide the framework necessary to assess the impact of treatment advances as they become available [49]. In the years to come, the ADAMS methodology can provide a marker of how well the country is doing with respect to the control and treatment of AD and other dementias. Regional studies in the USA will now have a national estimate with which to compare when exploring regional differences in disease patterns. The ADAMS data can also be enriched with other data collected from the ongoing HRS [14] and as part of the linkage of HRS to Medicare records allowing researchers to explore questions that might increase our understanding of, and ability to successfully address, the needs of an aging US population.

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