

Alzheimer Disease in the US Population

Prevalence Estimates Using the 2000 Census

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Context: Current and future estimates of Alzheimer disease (AD) are essential for public health planning.

Objective: To provide prevalence estimates of AD for the US population from 2000 through 2050.

Design: Alzheimer disease incidence estimates from a population-based, biracial, urban study, using a stratified random sampling design, were converted to prevalence estimates and applied to US Census Bureau estimates of US population growth.

Setting: A geographically defined community of 3 adjacent neighborhoods in Chicago, Ill, applied to the US population.

Participants: Alzheimer disease incidence was measured in 3838 persons free of AD at baseline; 835 persons were evaluated for disease incidence.

Main Outcome Measure: Current and future estimates of prevalence of clinically diagnosed AD in the US population.

Results: In 2000, there were 4.5 million persons with AD in the US population. By 2050, this number will increase by almost 3-fold, to 13.2 million. Owing to the rapid growth of the oldest age groups of the US population, the number who are 85 years and older will more than quadruple to 8.0 million. The number who are 75 to 84 years old will double to 4.8 million, while the number who are 65 to 74 years old will remain fairly constant at 0.3 to 0.5 million.

Conclusion: The number of persons with AD in the US population will continue to increase unless new discoveries facilitate prevention of the disease.

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CHANGING AGE structure of the US population markedly affects the occurrence of Alzheimer disease (AD). Because the disease has a great effect on the quality of life for affected individuals and caregivers and because it places heavy demands on the health care system, estimates of its occurrence and projections of future occurrence are essential for public health planning.

Available estimates^{1,2} vary in how data from source studies are applied to the US population, and, more importantly, in how AD is ascertained by source studies. Most studies have used a 2-stage approach, with a second stage of expert clinical evaluation required to measure disease. Some studies have used a screening approach, restricting second-stage evaluation for disease to persons failing a screening cognitive test. Others have evaluated disease in random fractions of both those failing and passing such a test, usually in several strata having different probabilities of random selection.

As prevalence estimates derived from restricting disease evaluation to those failing a screening test assume perfect screening test sensitivity,³ while random sampling of all fractions of the population does not, screening approaches typically give lower AD prevalence estimates. Differences resulting from using the 2 methods have been only infrequently examined,⁴ but may be large, depending on the severity of disease a study aims to detect. Gradual development of AD from normality results in a second variation in data collection methods. Although criteria⁵ for the disease reflect good conceptual agreement, translation into an operational cutoff point along the continuum between normality and advanced disease varies. A third variation in data collection is in "blinding" examiners performing the second-stage evaluations for disease to each subject's first-stage cognitive test performance. Although we are unaware of systematic investigations of blinding, judging from its importance in trials,⁶ its effect here seems potentially great.

Analytic variation occurs in applying study estimates to the US population.

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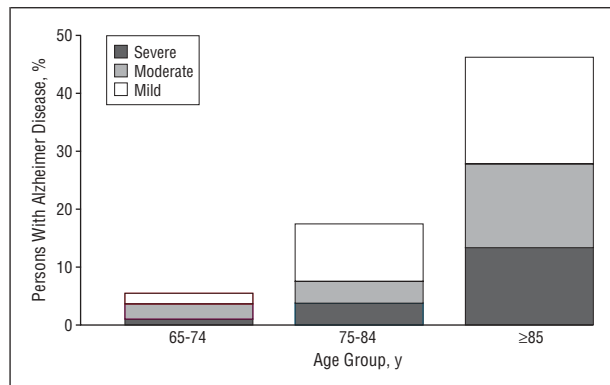


Figure 1. Prevalence of severe (Mini-Mental State Examination score, ≤ 9), moderate (Mini-Mental State Examination score, 10-17), and mild (Mini-Mental State Examination score, ≥ 18) Alzheimer disease, in each of 3 age groups, in the community population providing data for these estimates.

One method directly applies the prevalence of AD from a study to the number of people in the United States. The alternative life-table approach estimates prevalence from incidence of AD from a study. The first approach is more direct, but the second better adjusts for survival differences and takes advantage of incidence being a more accurate measure of disease occurrence, especially in studies of groups with large cultural differences.⁷

We use incidence estimates from a population study using stratified random sampling and blinded disease evaluation in a biracial urban community. We combine them with 2000 US census and National Center for Health Statistics mortality data to estimate prevalence of AD in the US population. We then project future population disease prevalence, using US Census Bureau high, middle, and low series of population growth projections.

METHODS

CHICAGO POPULATION STUDY

Estimates of AD incidence are from a study⁸ of a biracial (black and white), geographically defined community of 3 adjacent neighborhoods in Chicago, Ill—Morgan Park, Washington Heights, and Beverly. Of all residents older than 65 years, 79% participated. Each study data collection cycle consists of an in-home interview of all participants and clinical evaluation for AD of a stratified random sample. Alzheimer disease incidence was measured in a cohort of 3838 persons determined to be free of AD at baseline, with disease developing during an average interval of 4.1 years between the baseline cycle and cycle 2. Sampling for clinical evaluation was based on age, race, sex, and change in cognitive function from the first to the second cycle home interview of the entire cohort, with persons randomly selected for evaluation from all levels of cognitive change. All 835 persons examined received identical structured clinical evaluations by examiners blinded to population-interview cognitive testing and sampling category. Criteria for AD were those of the National Institute of Neurological and Communicative Disorders and Stroke–Alzheimer’s Disease and Related Disorders Association Working Group for probable AD,⁵ except that persons who met these criteria and had another condition-impairing cognition were retained.

STATISTICAL METHODS

We used the methods of Brookmeyer et al² with the following modifications. First, we calculated separate incidence estimates for 432 groups defined by single year of age, sex, 2 racial groups, and 3 educational groups, based on a logistic model weighted for the complex sample design with terms for age, age squared, race, educational groups, and follow-up interval. We then computed a weighted average incidence across the educational groups for each age, sex, and racial group. The weights were based on the current level of education from US census data⁹; future education was obtained by aging the current population. Second, instead of using the total population death rate for each age, sex, and racial group as the probability for the disease-free segment and multiplying that by 1.44 for the diseased segment, we distributed the total number of expected deaths between the diseased group and disease-free group using an iterative algorithm to obtain the ratio of 2.14 reported previously.¹⁰ Third, for the numbers of people alive at age 65 years and age-, sex-, race-, and birth cohort–specific death rates, we used National Center for Health Statistics life tables through 1999¹¹ and US census projected life tables up to 2050.¹² For the number of people in the US, we used the 2000 US census¹³ and the US Census Bureau estimates of US population growth through 2050.¹² We repeated the estimation for the year 2000, using different model specifications to examine sensitivity to variations in the logistic model.

We estimated the sample-weighted proportion of persons in each disease severity category by age group, using prevalence data from the baseline cycle of the Chicago study. Severity was classified by score on the Mini-Mental State Examination (MMSE)¹⁴ as mild (≥ 18), moderate (10-17),¹⁰⁻¹⁷ or severe (≤ 9).

RESULTS

CURRENT NUMBER OF PERSONS WITH AD

In 2000, we estimate there were 4.5 million people in the United States with AD. A fairly small number, 0.3 million (7%), were between the ages of 65 and 74 years, 2.4 million (53%) were between the ages of 75 and 84 years, and 1.8 million (40%) were 85 years of age and older. The estimate was insensitive to variations in statistical method; specifically, excluding a term for black race (not significant), including a term for sex (not significant), modeling educational level linearly by year, modeling educational level in different groups, and modeling age as a single linear term produced results within 0.5 million of the 4.5 million estimate.

In the Chicago population study, with most affected persons still living in the community, 48% of prevalent cases of AD were classified as mild, 31% as moderate, and 21% as severe. Prevalence of disease and proportion of severe disease increased with age (**Figure 1**). Among persons aged 65 to 74 years, 17% of these cases were severe compared with 20% among persons aged between 75 and 84 years and 28% among persons 85 years and older.

FUTURE NUMBER OF PERSONS WITH AD

Both the number of persons with AD in the US population and their age distribution will change substantially over the next 50 years (**Table**). Prevalence is expected to increase almost 3-fold to 13.2 million persons in 2050

Current and Projected Number of Persons With Alzheimer Disease (in Millions) Older Than 65 Years in the US Population by 3 Age Subgroups*

Year and Series	Age Group, y			Total
	65-74	75-84	≥85	
2000	0.3	2.4	1.8	4.5
2010				
Low	0.3	2.4	2.4	5.1
Middle	0.3	2.4	2.4	5.1
High	0.3	2.5	2.5	5.3
2020				
Low	0.3	2.5	2.7	5.5
Middle	0.3	2.6	2.8	5.7
High	0.4	2.7	3.1	6.2
2030				
Low	0.4	3.6	3.2	7.2
Middle	0.5	3.8	3.5	7.7†
High	0.5	4.1	4.0	8.6
2040				
Low	0.4	4.6	5.0	10.0
Middle	0.4	5.0	5.6	11.0
High	0.5	5.6	6.7	12.8
2050				
Low	0.4	4.2	6.7	11.3
Middle	0.4	4.8	8.0	13.2
High	0.5	5.6	9.9	16.0

*Estimates are projected by the low-, middle-, and high-series estimates of population growth of the US Census Bureau based on the 2000 US census.

†Value does not total precisely because of rounding.

(Table and **Figure 2**). To indicate the uncertainty in these future estimates, we bracket the estimates derived from the middle-series US Census Bureau estimates of population growth with estimates derived from the high- and low-series estimates of population growth. For 2010, the estimate derived from the middle series is 5.1 million persons with AD and is bracketed by an estimate derived from the low series of 5.1 million persons and an estimate derived from the high series of 5.3 million persons. By 2050, the uncertainty increases substantially. The estimate of 13.2 million persons with AD derived from the middle series is bracketed by a figure of 11.3 million derived from the low series and 16.0 million derived from the high series.

As rapid growth of the oldest age groups of the US population continues, the age distribution of AD will change (Table and **Figure 3**). The number of persons aged 75 to 84 years with the disease will double to 4.8 million by the year 2050. The number of persons older than 85 years with AD, however, will more than quadruple to 8.0 million. The number of persons aged between 65 and 74 years with the disease will remain fairly constant at 0.3 to 0.5 million.

Projected decline in death rates among persons older than 65 years in the US population to about half their current annual values by 2050¹¹ will, first, increase the number and proportion of persons who survive to the oldest ages where AD is most frequent, and, second, result in increased survival of persons with AD, and thus increased prevalence. We applied an estimate of the current ratio in survival of 1:2.14 to persons without the illness⁹ and assumed it will remain constant.

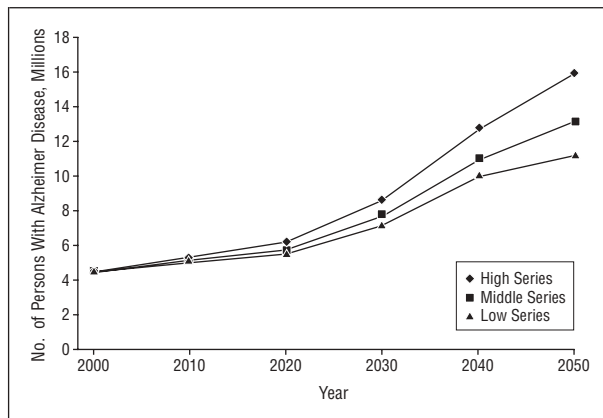


Figure 2. Projected number of persons in US population with Alzheimer disease using the 2000 US Census Bureau middle-series estimates of population growth, bounded by high- and low-series estimates.

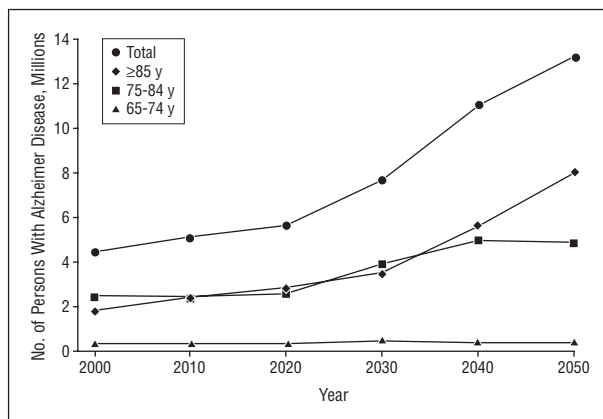


Figure 3. Projected number of persons in US population with Alzheimer disease by age groups, 65 to 74 years old, 75 to 84 years old, and 85 years and older, using the 2000 US Census Bureau middle-series estimate of population growth.

COMMENT

These estimates suggest that prevalence of AD in the US population will substantially increase, as older age groups increase in size. Further, the age distribution of the disease will change, as much of this increase will be attributable to the number of persons older than 85 years with AD.

COMPARABILITY TO ESTIMATES FROM OTHER STUDIES

Our estimate of AD prevalence in the year 2000 closely agrees with a projection from the earlier East Boston Study,¹ despite a different statistical method. The number of affected persons projected in 2050 is 35% higher than estimated from the East Boston Study because our methods assumes that projected increases in survival over the next 50 years will affect both persons with and without AD, with the ratio of survival among unaffected persons to survival among affected persons remaining constant at its present level.

Another study² provided lower estimates, especially for the absolute number of persons affected by AD in fu-

ture years. These differences appear due more to differences in the studies providing estimates of current AD occurrence rather than to fairly small differences in how these estimates of AD occurrence were applied to US Census Bureau estimates of population growth.¹⁵ Both this study and the earlier one suggest marked growth in numbers of persons affected by AD. The estimates from the prior study used 4 different source studies¹⁶⁻¹⁹ to estimate AD occurrence. One was the incidence phase of the East Boston Study,¹⁹ which used stratified random sampling to ascertain disease. The other 3 studies, however, used methods that gave lower estimates, especially in the oldest age groups. One¹⁷ used only medical records to identify cases; another¹⁸ eliminated the low-scoring 10% of persons from the dementia-free cohort and used a restrictive protocol to detect incident disease. Another¹⁶ examined a highly educated volunteer cohort that was likely healthier than the total population. Because the older subgroups of the US population will experience the greatest growth, these lower estimates of disease in the oldest aged groups result in large differences in projected AD prevalence in future years.

STRENGTHS AND LIMITATIONS OF THE STUDY

Strengths of this study include an estimation of population prevalence from source study incidence and a source study of a single population of black and white Americans that used random sampling for detailed evaluation from all strata of cognitive test performance and examiners blinded to prior cognitive test results. Weaknesses include a limited proportion of persons of Hispanic origin in this source study. While use of a single, rigorously designed study of AD is a strength, no single community is likely to exactly represent the entire country. The average educational level in the study community was fairly similar to that of the US current educational levels of persons older than 25 years suggesting that there will be little increase in the average educational level of people older than 65 years in the next 50 years. The effect of race on AD occurrence is unclear. We assumed the risk of death for persons with AD compared with that of unaffected persons will remain constant. Life expectancy with AD has a substantial effect on projected prevalence of the disease and is subject to such influences as improvements in care.

CONCLUSIONS

These estimates of a substantial increase in AD prevalence assume that the age-, race-, and education-specific risk of disease will remain constant over the next 50 years. The large public health challenge is to make these projections obsolete and irrelevant by discovering routes to the prevention of the illness through better understanding of its underlying biology and by discovery of modifiable risk factors.

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intellectual content (Drs Hebert, Scherr, Bienias, Bennett, and Evans); statistical expertise (Drs Hebert, Scherr, and Bienias); obtained funding (Dr Evans); administrative, technical, and material support (Drs Hebert, Bennett, and Evans); study supervision (Drs Bennett and Evans).

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REFERENCES

1. Evans DA. Estimated prevalence of Alzheimer's disease in the United States. *Milbank Q.* 1990;68:267-289.
2. Brookmeyer R, Gray S, Kawas C. Projections of Alzheimer's disease in the United States and the public health impact of delaying disease onset. *Am J Public Health.* 1998;88:1337-1342.
3. Rogan WJ, Gladen B. Estimating prevalence from the results of a screening test. *Am J Epidemiol.* 1978;107:71-76.
4. Albert M, Smith LA, Scherr PA, Taylor JO, Evans DA, Funtenstein HH. Use of brief cognitive tests to identify individuals in the community with clinically-diagnosed Alzheimer's disease. *Int J Neurosci.* 1991;57:167-178.
5. McKhann G, Drachman D, Folstein M, Katzman R, Price D, Stadlan EM. Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA Work Group under the auspices of Department of Health and Human Services Task Force on Alzheimer's Disease. *Neurology.* 1984;34:939-944.
6. Hennekens CH, Buring JE. *Epidemiology in Medicine.* Boston, Mass: Little Brown & Co; 1987:192-194.
7. Hendrie HC, Ogunniyi A, Hall KS, et al. Incidence of dementia and Alzheimer disease in 2 communities: Yoruba residing in Ibadan, Nigeria, and African Americans residing in Indianapolis, Indiana. *JAMA.* 2001;285:739-747.
8. Evans DA, Bennett DA, Wilson RS, et al. Incidence Alzheimer disease in a biracial urban community: relation to apolipoprotein E allele status. *Arch Neurol.* 2003; 60:185-189.
9. Continuous Measurement Office, Demographic Surveys Division, US Census Bureau. Census 2000 Supplementary PUMS: Educational Attainment. Available at: <http://www.census.gov/acs/Products/PUMS, 2002>. Accessed March 10, 2003.
10. Hebert LE, Scherr PA, McCann JJ, Beckett LA, Evans DA. Is the risk of developing Alzheimer's disease greater for women than for men? *Am J Epidemiol.* 2001; 153:132-136.
11. National Center for Health Statistics. US life tables 1965-1999. Hyattsville, MD. Also available at: http://www.CDC.gov/nchs/data/nvsr/nvsr50/nvsr50_06.pdf. Accessed March 10, 2003.
12. Population Projections Program, Population Division, US Census Bureau. Population and life tables, population projections of the United States by age, race, sex, Hispanic origin and nativity: 1999 to 2100. Available at: <http://www.census.gov/population/projections/nation/detail>. Accessed March 10, 2003.
13. US Census Bureau. Census 2000 Summary File 1 (Sf 1) 100-percent data, Tables pct12 and pct12b. Available at: <http://www.factfinder.census.gov, 2002>. Accessed March 10, 2003.
14. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res.* 1975; 12:129-138.
15. Brookmeyer R, Gray S. Methods for projecting the incidence and prevalence of chronic diseases in aging populations: application to Alzheimer's disease. *Stat Med.* 2000;19:1481-1493.
16. Kawas C, Gray S, Brookmeyer R, Fozard J, Zonderman A. Age-specific incidence rates of Alzheimer's disease: the Baltimore Longitudinal Study of Aging. *Neurology.* 2000;54:2072-2077.
17. Kokmen E, Chandra V, Schoenberg BS. Trends in incidence of dementing illness in Rochester, Minnesota, in three quinquennial periods, 1960-1974. *Neurology.* 1988;38:975-980.
18. Bachman DL, Wolf PA, Linn RT, et al. Incidence of dementia and probable Alzheimer's disease in a general population: the Framingham Study. *Neurology.* 1993; 43:515-519.
19. Hebert LE, Scherr PA, Beckett LA, et al. Age-specific incidence of Alzheimer's disease in a community population. *JAMA.* 1995;273:1354-1359.