Estimated Prevalence of Alzheimer's Disease in the United States

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AWARENESS OF ALZHEIMER'S DISEASE AS A MAJOR public health problem has increased strikingly among clinicians, researchers, policy makers and the general public over the past several years. As described by Alzheimer (1907), this term was used only for dementia arising in middle age. Such "presenile" dementia exhibits characteristic neuropathological findings, including neuritic plaques and neurofibrillary tangles. The term "Alzheimer's disease" is now applied, as well, to the much more common primary degenerative dementia occurring in later life, previously referred to as "senile dementia," because of apparent clinical and neuropathological (Tomlinson, Blessed, and Roth 1970) similarities regardless of age of onset. Many conditions other than Alzheimer's disease cause dementia among older persons, including certain strokes, Parkinson's disease, deficiency of vitamin B-12, and a wide range of uncommon conditions. Most population studies, however, suggest that the majority of moderate to severe cognitive impairment in older age groups is due to Alzheimer's disease, at least by clinical (rather than pathological) criteria for the disease. Regardless of age of onset, Alzheimer's disease is often devastating for affected individuals and their families. In terms of the total number of persons affected, however, Alzheimer's disease is increasingly a problem of the oldest old, that is, those 85 years of age and

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older. The occurrence of Alzheimer's disease is strongly associated with increasing age among those 65 years of age and older. With increasing life expectancy in developed countries, the impact of Alzheimer's disease will continue to increase.

Despite ongoing research efforts and consequent substantial increases in knowledge, many fundamental questions have not yet been answered. The etiology of the disease is unknown. Genetic, toxic, infectious, and degenerative influences are being studied (Katzman 1986). As with many other common chronic diseases, Alzheimer's disease likely has multiple risk factors. Further, the possibility that Alzheimer's disease itself may be a heterogeneous category has received increasing attention. The extent, if any, to which Alzheimer's disease, in mild or early cases, may form a continuum with normal cognitive function is uncertain. Several other common chronic diseases, most notably chronic obstructive lung disease and hypertension, appear to have no abrupt separation from normality.

At present, we do not have ideal means to estimate the number of individuals affected by Alzheimer's disease now or in the future. There are few studies of cognitive impairment in large, noninstitutionalized populations in either the United States or other countries, and still fewer studies that attempt differential diagnosis of the conditions responsible for the impairment. Most population-based studies (Hobson and Pemberton 1955; Essen-Moller 1956; Staff of the Mental Health Research Unit 1960; Parsons 1965; Gilmore 1974; Pfeiffer 1975; Gurland et al. 1983; Romaniuk 1983; Robins et al. 1984; Myers et al. 1984; Kramer et al. 1985; Kay et al. 1985; Copeland et al. 1987; Park and Ha 1988) have investigated cognitive impairment or dementia in general, without reference to specific underlying diagnoses. Fewer studies of noninstitutionalized populations (Kay, Beamish, and Roth 1964; Broe et al. 1976; Molsa, Marttila, and Rinne 1982; Folstein et al. 1985; Sulkava et al. 1985; Schoenberg, Anderson, and Haerer 1985; Shibayama, Kasahara, and Kobayashi 1986; Sayetta 1986; Pfeffer, Afifi, and Chance 1987; Schoenberg, Kokmen, and Okazaki 1987) provide clinical diagnoses of conditions causing dementia, such as Alzheimer's disease, and the sample sizes of some studies are small, especially for the oldest age groups. All of the studies in noninstitutionalized populations noted above have been concerned with prevalent disease. There have been no large-scale community-based studies of incident Alzhei-

mer's disease. Studies of incident disease may lead to improved understanding of both the risk factors for Alzheimer's disease and its course. Both are difficult to investigate in studies of prevalent disease.

In addition, it has been difficult to project the results of existing population-based studies to national populations. Pfeffer, Afifi, and Chance (1987) applied age-specific prevalence rates of clinically diagnosed Alzheimer's disease from a middle-class retirement community in southern California to the 1980 U.S. Census age distribution of whites aged 65 and over. The prevalence estimate for the United States population was 11.2 percent. The U.S. Congress, Office of Technology Assessment (1987) has provided estimates of 1.4 million persons with "severe dementia" in the United States in 1980, 2.4 million in 2000, 3.3 million in 2020, and 7.3 million in 2040. These last estimates, however, were not based directly on the results of a single population-based study.

The availability of data on disease prevalence from a large cohort of individuals from a defined United States community provided us the opportunity to estimate Alzheimer's disease prevalence in 1980 and project future prevalence rates through the year 2050 for the United States population 65 years of age and older.

Methods

The Community Study

East Boston, Massachusetts, is a geographically defined community of approximately 32,000 persons. This urban, working-class community has many persons of Italian descent. Educational attainment in East Boston is low compared with other Boston neighborhoods and with the United States population as a whole. One of four centers of the National Institute of Aging Established Populations for Epidemiologic Studies of the Elderly (EPESE) project (Cornoni-Huntley et al. 1986) is located in the community.

These community studies employed a two-stage design. In the first stage, brief performance tests of certain areas of cognitive function were administered to all participating community residents 65 years of age and older in their homes (Scherr et al. 1988). The second stage con-

sisted of clinical evaluation of individuals selected according to the results of these brief performance tests. Selection was designed to permit estimates of disease prevalence in the community from the sample undergoing clinical evaluation (Evans et al. 1989).

The first stage began in January 1982. A complete census of the community was done, and all noninstitutionalized individuals aged 65 years or older were invited to participate by responding to a structured questionnaire administered in their homes by trained interviewers. This questionnaire included a broad range of items concerning medical and social problems of older persons and brief performance tests of certain areas of cognitive function. Interview language was chosen by the participant. Twenty-five percent of study participants were born in Italy; 34 percent of those born in Italy and none of those born in the United States chose to have the interview in Italian. The tests included immediate and delayed recall of a brief, three-sentence story. Participants were divided into groups according to their memory test performance, and individuals were selected for clinical evaluation for dementing illness from all levels of performance, sampling the largest proportion from the poor performance group.

Virtually all (99.8 percent) households in the study community were included in the census. Of 4,485 age-eligible residents, 3,809 (85.0 percent) participated in the population survey. Of these participants, 3,623 had memory testing (80.8 percent of the age-eligible residents of the community), while 188 persons did not receive memory testing, usually because they participated through proxy respondents. Of 714 persons sampled for clinical evaluation from those participating in the population survey, 54 died prior to being invited to undergo clinical evaluation; 467 (70.8 percent of the surviving eligible individuals) were evaluated, and 193 declined evaluation.

The second-stage clinical evaluations included neuropsychological testing, neurological examination, brief psychiatric evaluation, laboratory evaluation, brief review of the medical history, and interview of a significant other individual for each participant. All prescription and over-the-counter medications used during the previous two weeks were inspected and identified. Each clinical evaluation required, on average, approximately two and one-half hours. Structured instruments were used, and the examiners were blinded to performance on the population-survey cognitive testing.

Disease Classification

From the results of the clinical evaluation, each individual was classified in two ways: first, according to the presence and severity of any cognitive impairment; and, second, according to the conditions responsible for the impairment, with each of a series of diagnoses, including Alzheimer's disease, rated as absent, possible, or probable. The probable category corresponds to the probable Alzheimer's disease category of the criteria developed by the joint working group of the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA criteria) (McKhann et al. 1984). The NINCDS-ADRDA criteria consider absence of other diagnoses of dementing illness in determining probability of Alzheimer's disease. This restriction, although useful in clinical practice, results in underestimation of disease prevalence in a population, as the presence of one disease leading to dementia does not exclude the occurrence of another. Therefore, for the estimates presented here, we calculated Alzheimer's disease prevalence, omitting the NINCDS-ADRDA restriction that any other diseases possibly accounting for dementia be absent for the diagnosis of probable Alzheimer's disease. The difference in estimated prevalence of Alzheimer's disease if the restriction is applied or omitted was small in the East Boston population. If the restriction was omitted, the estimated prevalence of Alzheimer's disease among those 65 years of age and older in the East Boston community was 11.6 percent; if it was applied, the estimate fell slightly, to 10.3 percent (Evans et al. 1989).

Estimates of the Prevalence of Alzheimer's Disease for the United States Population

The prevalence estimates of Alzheimer's disease for the United States population were obtained by a three-step process. In the first step, the results for the sample undergoing clinical evaluation were summarized using a logistic model. The second step was projecting these results to the East Boston population, and the third step was projecting East Boston results to the United States population, both present and future.

At the first step, the observed proportions with Alzheimer's disease

in the sample of 467 persons undergoing clinical evaluation were determined for subgroups stratified by five-year age group, sex, level of education, and screening memory test performance. Because some of these groups in the sample were small, a logistic regression model was used to smooth the observed proportions and to provide estimates of the effects of age (as a linear term), sex, education, and screening memory performance on disease prevalence. At the second step, the East Boston population was divided into subgroups by age (65–69, 70–74, 75–79, 80–84, 85–89, 90+), sex, years of formal education (0–7, 8, 9–11, 12+), and memory test group. The disease prevalence in each subgroup of the East Boston population was then estimated using the smoothed prevalences, obtained by applying the logistic regression coefficients from the first step to the subgroup characteristics (sex, education group, memory test group, and mean age). The covariance of the subgroup estimates was obtained using the logistic regression covariance matrix (Bishop, Fienberg, and Holland 1975). The memory-group strata were then combined to give age-, sex-, and education-specific prevalences for East Boston with an estimated covariance matrix.

In the third step, community prevalence estimates within each subgroup were applied to the distribution of age, sex, and education groups for the United States population in 1980. U.S. Bureau of the Census population figures are used for the United States population in 1980 by age, sex, and years of formal education (Miller 1983). Standard error estimates were obtained using the covariance estimates for the prevalences in East Boston and 95 percent confidence intervals were derived. Steps one, two, and three were also repeated, omitting adjustment for level of education, but adjusting for age and sex.

The community-prevalence estimates from East Boston were also applied to United States population projections by age and sex from 1990 to 2050 according to decade, in order to assess the potential public health impact in future years. In applying the East Boston estimates to future population projections, there are two sources of uncertainty: possible errors in the prevalence estimates in East Boston and possible errors in the United States population projections. To approximate the combined impact of these two sources of error, the confidence intervals from the East Boston prevalence estimates were applied to three series of population projections: the U.S. Bureau of the Census high, middle, and low series (Spencer 1984). These series vary with respect to as-

sumptions regarding fertility, mortality, and net immigration. The mortality assumptions in all three series reflect revised mortality rates for those 95 years of age and older (Faber 1982).

East Boston residents 65 years of age and older have fewer years of formal education than the national average for this age group. Unpublished, preliminary data from our studies suggest that rates of clinically diagnosed Alzheimer's disease may be higher among those with lower educational attainment. At this time, the interpretation of an association between education and rates of Alzheimer's disease in cross-sectional data is uncertain (Kittner et al. 1986; Berkman 1986). The estimates of Alzheimer's disease prevalence for the United States population presented here are adjusted for the difference in level of formal education between the East Boston and United States populations. In addition, overall estimates without adjustment for education, which are higher, are also given. For the years 1990 through 2050, the distributions for education were calculated under the assumption that there was no differential mortality with respect to education. Thus, the percent distribution of years of education for those aged 65 to 74 in 1980 would be the same as the percent distribution for those aged 75 to 84 in 1990.

Results

Estimates of Alzheimer's Disease Prevalence for the United States Population in 1980

The estimated prevalences of probable Alzheimer's disease for age, sex, and education strata of the East Boston population 65 years of age and older were applied to the 1980 United States population. The estimated number of persons 65 years of age or older in the United States population with probable Alzheimer's disease in 1980 was 2.88 million (95 percent confidence interval: 2.17–3.59 million). This is 11.3 percent (8.5–14.1) of the persons in this age group.

Within the group 65 years of age and older, the proportion of individuals with Alzheimer's disease rises sharply with increasing age.

Among those 65 to 74 years of age, 3.9 percent (1.7–6.1) were estimated to have probable Alzheimer's disease. For those 75 to 84 years of age, this prevalence rises to 16.4 percent (12.0–20.6), and among those 85 years of age and older, to 47.55 percent (37.7–57.4). In terms of the absolute number of affected individuals in the United States population in 1980, however, the highest number were from the 75- to 84-year-old age group. Among those 65 to 74 years old, there were 0.61 million (0.26–0.96) persons with Alzheimer's disease, compared with 1.25 million (0.92–1.58) 65 to 74 years old and 1.02 million (0.81–1.24) 85 years old and over.

Projections of Alzheimer's Disease Prevalence for the United States Population from 1990 through 2050

The results of applying the age-, sex-, and education-specific estimates of disease prevalence to projections of the United States population in the older age groups suggest that the prevalence of Alzheimer's disease will grow substantially. The projected rate of growth varies somewhat according to whether the high, middle, or low series projections are used, but the increase in the number of individuals affected by Alzheimer's disease is large with any of the three projection series. In the year 2050, the number of persons in the United States population 65 years of age and older affected by Alzheimer's disease is estimated to be 7.50 million (4.39–10.6) using the low series projections, 10.3 million (6.16–14.4) using the middle series, and 14.3 million (8.77–19.8) using the high series. These projections for the high, middle, and low series are shown in figure 1 and table 1. The limits indicated in parentheses for these and other future projections are not 95 percent confidence limits in the usual sense. Rather, they are limits calculated by applying the upper and lower confidence limits for the cross-sectional community estimates to the Census projections at a given date. Thus, they do not take forecasting error into account. As discussed above, a better approximation of both sources of uncertainty in the projections comes from considering these limits together with the three U.S. Bureau of the Census series of population estimates.

Projections of Alzheimer's Disease Prevalence by Age Group. Inspection of projections from 1990 to 2050 by age group (figure 2 and table 1) shows that increases in the oldest age groups will account for

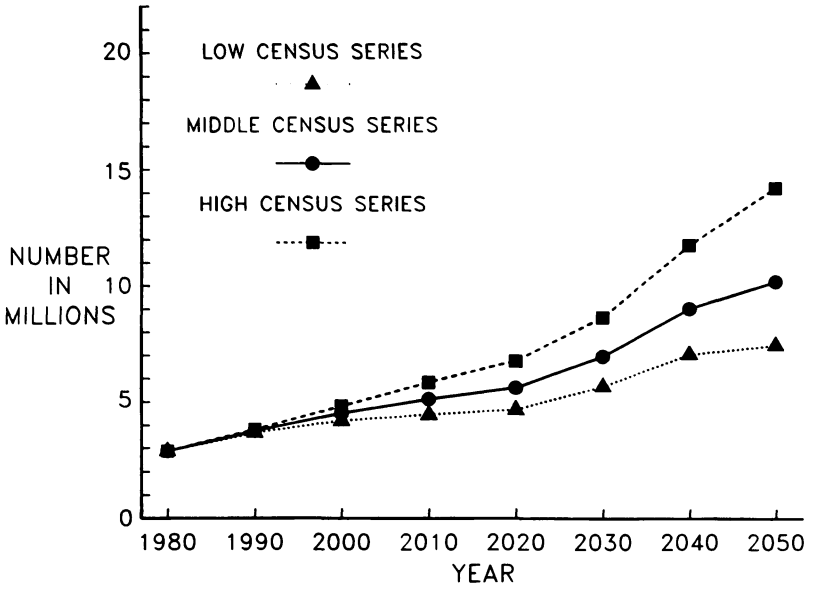

FIG 1. Projected number of persons 65 years of age or older with probable Alzheimer's disease in the United States population from 1980 through 2050 using low, middle, and high U.S. Census projections of population growth. Disease prevalence data from studies in East Boston, Massachusetts, adjusted for years of education.

most of the projected increase in prevalence of Alzheimer's disease over this period. Using the middle-series Census projections, for example, the number of persons with Alzheimer's disease in the 65- to 74-year age group rises only moderately from 0.61 million (0.26–0.96) in 1980 to 0.74 million (0.13–1.34) in 2050. In contrast, the number of affected individuals 85 years of age and older rises almost seven-fold, from 1.02 million (0.81–1.24) in 1980 to 7.07 million (4.46–9.67) in 2050.

Estimates Unadjusted for Educational Attainment. If the adjustment for education is not performed, the resulting estimates of Alzheimer's disease prevalence are substantially higher. Figure 3 gives prevalence estimates without adjustment for education for the United States population from 1980 through 2050. In 1980, the unadjusted estimate of number of persons aged 65 and older with Alzheimer's disease was 3.44 million (2.71–4.17), as contrasted with the education-adjusted estimate of 2.88 million. By 2050, this difference between the

TABLE 1
Estimated Number (in millions) of Persons in the United States Population with Clinically Diagnosed Alzheimer's Disease from 1980 through 2050 by Age Group, Using Three Different U.S. Census Population Projections

Year	U.S. Census projection series	65–74	75–84	85+	Total aged 65 and over
1980		0.61 (0.26–0.96)[a]	1.25 (0.92–1.58)	1.02 (0.81–1.24)	2.88 (2.17–3.59)
	High	0.59 (0.22–0.96)[b]	1.59 (1.12–2.05)	1.62 (1.28–1.97)	3.80 (2.85–4.76)
1990	Middle	0.59 (0.22–0.95)	1.57 (1.12–2.03)	1.59 (1.25–1.93)	3.75 (2.80–4.70)
	Low	0.58 (0.22–0.95)	1.55 (1.10–2.01)	1.53 (1.20–1.86)	3.67 (2.74–4.60)
	High	0.55 (0.19–0.92)	1.71 (1.10–2.33)	2.55 (1.95–3.16)	4.82 (3.49–6.15)
2000	Middle	0.54 (0.18–0.90)	1.65 (1.06–2.24)	2.32 (1.76–2.87)	4.51 (3.25–5.77)
	Low	0.53 (0.18–0.88)	1.59 (1.02–2.16)	2.07 (1.58–2.57)	4.19 (3.00–5.38)
	High	0.56 (0.14–0.98)	1.71 (1.01–2.40)	3.57 (2.56–4.59)	5.84 (4.00–7.68)
2010	Middle	0.54 (0.14–0.94)	1.61 (0.96–2.25)	2.98 (2.12–3.83)	5.12 (3.48–6.76)
	Low	0.51 (0.13–0.90)	1.48 (0.88–2.09)	2.46 (1.75–3.17)	4.46 (2.99–5.93)
	High	0.77 (0.14–1.40)	1.84 (0.95–2.72)	4.17 (2.87–5.47)	6.78 (4.34–9.22)
2020	Middle	0.73 (0.13–1.33)	1.68 (0.87–2.48)	3.22 (2.20–4.23)	5.62 (3.52–7.72)
	Low	0.69 (0.12–1.26)	1.53 (0.79–2.26)	2.46 (1.68–3.24)	4.68 (2.86–6.50)
	High	0.93 (0.17–1.69)	2.67 (1.23–4.11)	5.07 (3.33–6.82)	8.68 (5.17–12.2)
2030	Middle	0.86 (0.16–1.56)	2.40 (1.11–3.68)	3.73 (2.43–5.03)	6.99 (4.05–9.92)
	Low	0.80 (0.15–1.46)	2.14 (0.99–3.30)	2.74 (1.78–3.71)	5.69 (3.20–8.18)
	High	0.82 (0.15–1.48)	3.27 (1.52–5.02)	7.72 (4.87–10.6)	11.8 (7.02–16.6)

continued

TABLE 1 continued

Year	U.S. Census projection series	65–74	75–84	85+	Total aged 65 and over
2040	Middle	0.74	2.84	5.49	9.07
		(0.14–1.33)	(1.32–4.37)	(3.44–7.55)	(5.28–12.9)
	Low	0.67	2.49	3.92	7.08
		(0.12–1.22)	(1.16–3.83)	(2.43–5.40)	(4.02–10.1)
	High	0.84	2.92	10.5	14.3
		(0.15–1.53)	(1.36–4.47)	(6.72–14.4)	(8.77–19.8)
2050	Middle	0.74	2.46	7.06	10.2
		(0.13–1.34)	(1.15–3.77)	(4.46–9.67)	(6.16–14.4)
	Low	0.66	2.09	4.74	7.50
		(0.12–1.20)	(0.98–3.21)	(2.96–6.52)	(4.39–10.6)

[a] For 1980 estimates, numbers in parentheses are 95% confidence limits.
[b] The limits indicated in parentheses for this and future projections are not confidence limits in the usual sense. Rather, they are limits calculated by applying the upper and lower confidence limits for the cross-sectional community estimates to the census projections at a given date. Thus, they do not take forecasting error into account. See text.

adjusted and unadjusted estimates widens. Using the middle Census series projections, in this year the estimated number of affected persons without adjustment for education is 15.4 million (13.1–17.8), compared with the adjusted estimate of 10.3 million.

Discussion

We estimate the prevalence of Alzheimer's disease in the United States population in 1980 to have been 2.88 million people, or 11.3 percent of those 65 years of age and older. The public health impact of Alzheimer's disease will increase strongly in the future as rapid growth of the oldest age groups of the population continues.

Strengths and Limitations of the Estimates

Any estimates of Alzheimer's disease prevalence must be interpreted with some caution. Although there is a reasonable consensus

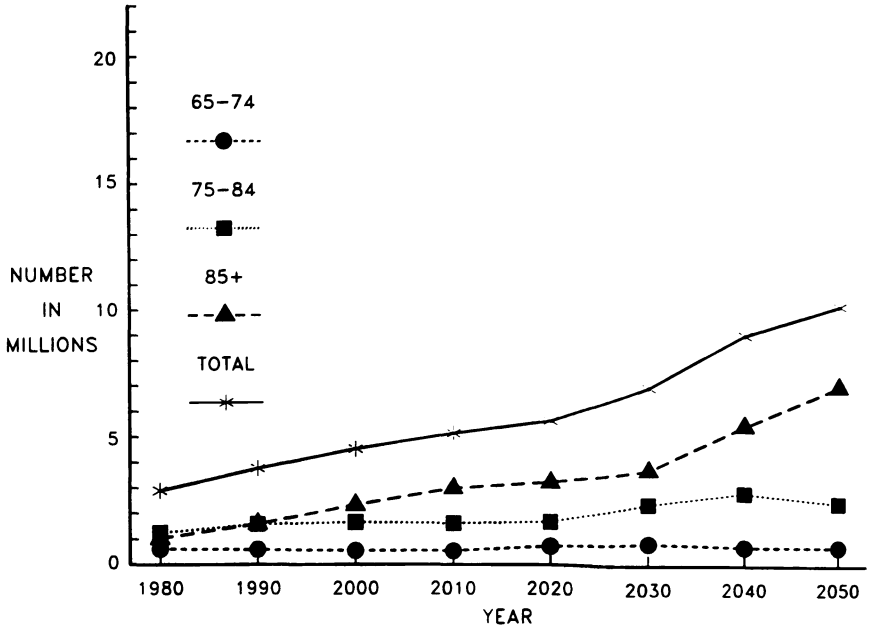

FIG 2. Projected number of persons 65 years of age or older with probable Alzheimer's disease in the United States population from 1980 through 2050 by three age subgroups, using U.S. Census middle projection of population growth. Disease prevalence data from studies in East Boston, Massachusetts, adjusted for years of education.

(McKhann et al. 1984) about the concepts forming the clinical diagnosis of Alzheimer's disease, the translation of these concepts into specific operational criteria is not a matter of secure agreement (Kay et al. 1985; Henderson and Jorm 1987). This is especially true with regard to the type and severity of cognitive impairment thought to be characteristic of the disease. Therefore, criteria used in different studies will range along a spectrum, and prevalence estimates from these studies will vary substantially according to placement of cut-points along this diagnostic continuum. This variation especially affects studies in community populations in which mild disease that is difficult to separate from normal may be expected to predominate.

Estimates of Alzheimer's disease prevalence used here are based on uniform, structured clinical evaluations by blinded examiners of individuals sampled from a defined community population. These evaluations permitted clinical diagnosis of various conditions responsible for

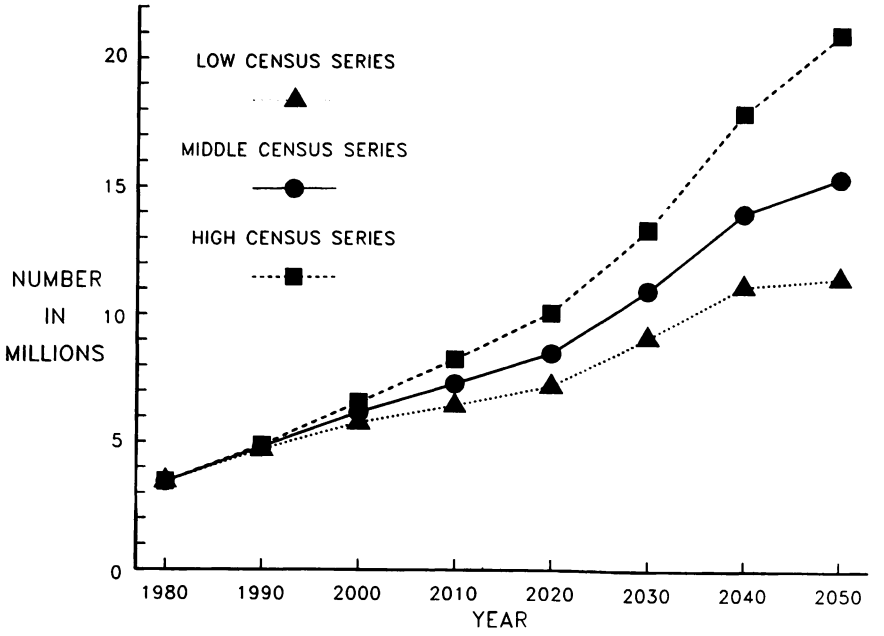

FIG 3. Projected number of persons 65 years of age or older with probable Alzheimer's disease in the United States population from 1980 through 2050 using low, middle, and high U.S. Census projections of population growth. Disease prevalence data, from studies in East Boston, Massachusetts, omitting adjustment for years of education.

cognitive impairment in this population. Conditions responsible for dementia other than Alzheimer's disease were relatively uncommon in this population (Evans et al. 1989) and the confidence limits about population prevalence estimates for them are large. Therefore, we do not attempt to estimate the prevalence of these other dementing conditions in the United States population. For estimation of Alzheimer's disease, the sample size is relatively large and includes a substantial number of individuals 85 years of age and older, the age group for which disease prevalence is highest. The clinical criteria for Alzheimer's disease correspond to NINCDS-ADRDA criteria (McKhann et al. 1984). For the purpose of estimating disease prevalence in the population, the NINCDS-ADRDA restriction that the presence of a coexisting diagnosis of another dementing illness removes a person from the probable Alzheimer's disease category was not used. (See the discussion of disease classification above and Evans et al. [1989].) The ability to as-

sign clinical diagnoses, inclusion of a relatively large number of persons aged 85 and over, use of structured, uniform procedures, and selection of subjects from all strata of performance on a population screening test are unusual compared with most existing population studies. Each of these features increases the validity of the estimates from the study.

Our estimate of Alzheimer's disease prevalence is in close agreement with the 11.2 percent reported by Pfeffer, Afifi, and Chance (1987) from a study using different methods. This estimate is substantially higher than those from some other population-based studies, however, and is also higher than the estimate of 1.4 million affected persons in the 1980 United States population provided by the U.S. Congress, Office of Technology Assessment (OTA) (1987). Three reasons account, at least in part, for these differences. First, and most important, the OTA estimate (U.S. Congress, Office of Technology Assessment 1987) and some earlier studies (Molsa, Marttila, and Rinne 1982; Schoenberg, Anderson, and Haerer 1985) were intentionally restricted to severe disease, whereas the present study includes the full range of behaviorally manifest disease present in the community.

Such restriction substantially reduces estimates of disease prevalence. For example, of those with probable Alzheimer's disease in the East Boston study, 26 percent had severe cognitive impairment, 51 percent moderate impairment, and 23 percent mild impairment. Second, some previous community-based studies have confined selection of subjects for clinical evaluation to those who scored poorly on population screening instruments. This, again, leads to substantial underestimates of disease prevalence in the population because the large group of individuals passing the screening tests will include a number of persons with disease. Third, some previous studies (Kokmen et al. 1989) were based on records of those coming to medical attention for dementia and having the diagnosis entered in the record, but the proportion of individuals whose dementia is formally recognized and diagnosed during routine delivery of medical care is unknown and, perhaps, small. The East Boston study, on the other hand, was based on a sample of persons from a total community survey examined by a single research team.

Prevalence estimates from a cross-sectional study such as ours tend to exclude cases with a rapidly progressive course because of their selective removal from the community by death or institutionalization. Further, our study was restricted to noninstitutionalized individuals. Rates of Alzheimer's disease among institutionalized persons are almost cer-

tainly higher. Preliminary data (Hing 1987) from the 1985 U.S. National Nursing Home Survey suggest that 47 percent of nursing-home residents 65 years of age and older were diagnosed as having "senile dementia or chronic organic brain syndrome." Rovner et al. (1986) found that 28 of 50 residents of a United States intermediate-care nursing home met DSM III criteria (American Psychiatric Association 1980) for primary degenerative dementia. Thus, despite the fact that our estimates are higher than some previous ones, to the extent that they are affected by these limitations, they may well understate the full impact of the disease.

Estimates of the future impact of Alzheimer's disease are determined more by factors other than the current overall prevalence estimate. The rate of projected growth in prevalence of Alzheimer's disease depends strongly on the current age distribution of the disease and the projected rate of growth of the oldest population age groups. Therefore, both of these factors deserve close examination.

With regard to the age distribution of disease in the community population, the high proportion of individuals meeting criteria for probable Alzheimer's disease in the group aged 85 years and older has a strong influence on projections of disease prevalence for the total population. An excess of mildly impaired individuals in the oldest age groups relative to the younger groups would raise the possibility that the increase in disease prevalence with age was overestimated. Therefore, we examined age-specific estimates of severe, moderate, and mild cognitive impairment in the community population, without considering the condition responsible for the impairment. For severe cognitive impairment, the prevalence was 0.3 percent (0–0.9) in the 65- to 74-year-old group, 5.6 percent (1.9–9.2) in the 75- to 84-year-old group, and 19.6 percent (11.1–28.1) in the group 85 years of age and older. For moderate cognitive impairment, the prevalence for the three age groups was 4.6 percent (0.8–8.5), 14.3 percent (9.5–19.1), and 31.3 percent (21.3–41.4). For mild cognitive impairment the prevalence for the three age groups was 14.3 percent (7.6–21.0), 27.0 percent (20.0–33.9), and 28.6 percent (18.9–38.2). Thus, the increase in prevalence of cognitive impairment with age is most strikingly seen with severe and moderate impairment. Any estimate of the point prevalence of Alzheimer's disease is strongly dependent on disease criteria and how they are implemented. These data suggest, however, that if more restrictive cut-points were to be used for disease according to severity of

impairment, the prevalence rates for any one age group would change, but the striking increase in disease prevalence with age would remain.

With regard to projected population changes, some projections suggest that future growth of the oldest age groups of the population may substantially exceed the U.S. Bureau of the Census projections used here because of greater reductions in mortality (Manton 1982; Vaupel and Gowan 1986). The estimated increase in the prevalence of Alzheimer's disease in the United States population is largely a consequence of projected increases in size of the oldest age groups, especially those aged 85 years and older. Therefore, if increases in these age groups were to substantially exceed Census Bureau estimates, the projected prevalence of Alzheimer's disease would be higher. There have been few previous projections of future prevalence of Alzheimer's disease with which to compare our results. Our estimate of the proportion of those 65 years of age and older affected in the year 2000 (using the low Census series of 12.5 percent, middle Census series of 12.9 percent, high Census series of 13.3 percent) is lower than that the U.S. Congress, OTA (1987), reflecting the restriction of the OTA estimates to severe dementia.

A substantial limitation of our estimates is that no single community, including the one for the present study, is likely to be representative of the total United States population. Moreover, risk factors for Alzheimer's disease are largely unknown, so that comparison of a community's characteristics to those of the United States population is not useful. Because level of formal education may be a risk factor for Alzheimer's disease, prevalence estimates are presented adjusted for this potentially confounding variable. The adjustment for difference in average level of education between the study community and the United States population affects the estimated current prevalence of disease. The projected future estimates of Alzheimer's disease prevalence are also adjusted for anticipated changes in educational attainment in the United States population. This adjustment has a major effect on estimates of disease prevalence in the future because of the strong trend toward greater educational attainment among older persons (Taeuber 1983; Siegel and Davidson 1984). If this adjustment is not performed, substantially higher estimates of future disease prevalence are obtained, as may be seen from comparing figures 1 and 3. The assumption in making these projections presented here, that there is no differential

mortality by education, is in accord with recent U.S. Bureau of the Census estimates (Siegel and Davidson 1984), but may not be completely correct (Kitagawa and Hauser 1973). If lower educational attainment is associated with higher mortality, projected future educational levels in the oldest age groups of the United States population may be higher than those used here, and the projected overall prevalence of Alzheimer's disease may be correspondingly overestimated.

In the projections, age is modeled using the mean age of each subgroup in the East Boston community in 1982. It seems very likely, however, that the mean age of the oldest age groups of the United States population will increase substantially. If the prevalence of Alzheimer's disease continues to rise with increasing age within the oldest age groups, the projected prevalence of Alzheimer's disease will be underestimated. Finally, although the study providing data for these estimates is large compared with previous investigations, the confidence limits about many of our current prevalence estimates are wide. An additional source of uncertainty in applying these estimates to future projections is possible error in United States population projections. Although we have approximated the combined impact of these two sources of error by applying the confidence intervals from the East Boston prevalence estimates to three series of U.S. Bureau of the Census population projections, this may understate the uncertainty, especially because, as noted above, it is possible that Bureau of the Census projections underestimate growth of the oldest age groups.

Implications

Despite their limitations, these estimates indicate the overall present and future magnitude of the problem. Statements by institutional bodies (Royal College of Physicians of London 1980; Council on Scientific Affairs, American Medical Association 1986; U.S. Congress, Office of Technology Assessment 1987) and by individuals (Plum 1979; Brody 1982; Weiler 1987) suggest that both the rapidly growing seriousness of Alzheimer's disease as a public health issue and a need for vigorous action are now widely appreciated. The estimates presented here suggest several areas in which action will be necessary.

An increase in the number and size of studies in large noninstitutionalized populations, particularly studies able to provide accurate es-

timates of disease incidence, would aid planning. The increase in prevalence of Alzheimer's disease will place substantially increased demands on the delivery of long-term care services to older persons in the United States and other developed countries experiencing similar demographic changes. Much of the information necessary for planning to deal with this development is not presently available. Medical care costs are only one component of the economic impact of Alzheimer's disease. Currently available estimates of the costs of Alzheimer's disease vary widely. This variation arises, at least in part, from substantial limitations in the data used to calculate these estimates. Hay and Ernst (1987), using an estimate of 1.5 million cases of Alzheimer's disease in the United States population in 1983 (substantially lower than our estimate), calculated a total net annual cost to society from the disease of approximately $30 billion. Huang, Cartwright, and Hu (1988), using an estimate of 3.66 million cases of Alzheimer's disease in the United States population in 1985 (somewhat higher than our 1990 estimate based on the middle census series), calculated direct and indirect costs of the disease at $88 billion.

Those with Alzheimer's disease are at increased risk of institutionalization, but we have little ability to quantify this risk for community-dwelling persons. Similarly, we know little of the disease features that determine need for long-term care or of the role of noninstitutional forms of long-term care in this disease. On a more general level, there are few studies of predictors of use of institutional or other long-term-care services in community populations. The factors that enable some individuals with severe impairments of physical or cognitive function to remain in their homes while others, with similar levels of function, are placed in nursing homes or other institutions are not identified. The increasing severity of Alzheimer's disease as a public health problem combined with this lengthy list of unknowns raise the question of whether the current level of support for relevant health-care services research in the United States is adequate.

As with other common chronic diseases, an ultimate goal of research concerning Alzheimer's disease is prevention of the condition. At the present, etiologic factors remain undetermined, but it is essential that this long-term goal not be obscured. The formulation and testing of hypotheses regarding the etiology of Alzheimer's disease must have a very high priority. Support for Alzheimer's disease research has been

growing at an accelerating pace over the last several years. The rapidly increasing magnitude of the problem outlined here suggests that even greater emphasis on both basic and applied research is necessary.

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