

# Prevalence of dementia after age 90

## Results from The 90+ Study



M.M. Corrada, ScD  
R. Brookmeyer, PhD  
D. Berlau, PhD  
A. Paganini-Hill, PhD  
C.H. Kawas, MD

Address correspondence and  
reprint requests to Dr. María M.  
Corrada, 1513 Hewitt Hall,  
University of California Irvine,  
Irvine, CA 92697-1400  
mcorrada@uci.edu

### ABSTRACT

**Background:** Although the prevalence of dementia increases with age from ages 65 to 85, whether this increase continues after age 90 is unclear. Most studies reporting on dementia prevalence do not have sufficient participants to estimate prevalence for specific ages and sexes above age 90. Here, we estimate age- and sex-specific prevalence of all-cause dementia in the oldest-old, those aged 90 and older.

**Methods:** Participants are 911 elderly from The 90+ Study, a population-based study of aging and dementia in people aged 90 and above. Dementia was diagnosed using in-person examinations as well as telephone and informant questionnaires.

**Results:** The overall prevalence of all-cause dementia was higher in women (45%, 95% CI = 41.5–49.0) than men (28%, 95% CI = 21.7–34.2). Among women, prevalence increased with age after age 90, essentially doubling every 5 years. A lower prevalence of dementia was significantly associated with higher education in women but not in men.

**Conclusions:** In a very large sample of participants aged 90 and older, prevalence of all-cause dementia doubled every 5 years for women but not men. *Neurology*® 2008;71:337–343

### GLOSSARY

**ADL** = Activities of Daily Living; **CASI-short** = Cognitive Abilities Screening Instrument; **CSHA** = Canadian Study of Health and Aging; **DQ** = Dementia Questionnaire; **DSM-IV** = Diagnostic and Statistical Manual of Mental Disorders, 4th edition; **DSRS** = Dementia Severity Rating Scale; **FAQ** = Functional Activities Questionnaire; **LEILA75+** = Leipzig Longitudinal Study of the Aged; **MMSE** = Mini-Mental State Examination.

Dementia is relatively common in the elderly and is associated with increased functional impairments, institutionalization, and mortality. The prevalence of all-cause dementia increases exponentially from ages 65 to 85, doubling every 5 years.<sup>1</sup> However, it is not clear whether the prevalence continues to increase after age 85 or whether it plateaus in the highest age ranges. The few studies that have reported on dementia prevalence in the oldest-old show disparate results with some studies finding that prevalence continues to increase with age after 90<sup>2–4</sup> whereas others suggest that prevalence plateaus.<sup>5,6</sup> As the oldest-old are the fastest growing segment of the United States population, accurate estimates of dementia prevalence are crucial for public health planning.

Because of difficulties in finding, recruiting, and diagnosing the oldest-old, most prevalence studies have few very elderly individuals. Consequently, most studies have estimated prevalence for 90+ subjects as a whole group, with only a handful of publications reporting age- and sex-specific estimates.

The present study estimates age- and sex-specific prevalence of all-cause dementia in individuals aged 90 and above who are part of The 90+ Study, one of the largest epidemiologic studies specifically designed to study aging and dementia in the oldest-old.

Supplemental data at  
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*e-Pub ahead of print on July 2, 2008, at [www.neurology.org](http://www.neurology.org).*

From the Department of Neurology (M.M.C., C.H.K.), Department of Neurobiology & Behavior (C.H.K.), and Institute for Brain Aging and Dementia (M.M.C., D.B., C.H.K.), University of California Irvine; Department of Biostatistics (R.B.), Johns Hopkins Bloomberg School of Public Health, Baltimore, MD; and Department of Preventive Medicine (A.P.-H.), Keck School of Medicine, University of Southern California, CA.

Funded by a grant from the National Institute of Health (R01AG21055) and the Al and Trish Nichols Chair in Clinical Neuroscience.

*Disclosure:* The authors report no disclosures.

**METHODS Study population.** Participants were drawn from The 90+ Study, a population-based longitudinal study of aging and dementia in persons aged 90 and older. These subjects are survivors from the Leisure World Cohort Study, an epidemiologic investigation of a retirement community in Orange County, CA (Leisure World, Laguna Woods) initiated in the early 1980s. The cohort is primarily Caucasian, well-educated, upper middle-class, and mostly female (66%).<sup>7</sup> The 1,151 participants from the original cohort aged 90 years and older on January 1, 2003, were invited to join The 90+ Study. As of July 1, 2006, 941 participants had been recruited into the study. Although most of the recruited participants still lived in the same county (60%), many had moved to other parts of California (24%) or out of state (16%).

**Assessments.** The 90+ Study has different levels of participation: participants examined in person, those interviewed over the phone, and those on whom an informant provides all information (by informant). At the baseline evaluation, participants (or their informants) were mailed a questionnaire regarding demographics, past medical history, and medication use. For those participants seen in person, the initial questionnaire was reviewed at the time of the visit and additional procedures were performed including a neurologic examination and a battery of neuropsychological tests (including the Mini-Mental State Examination [MMSE]<sup>8</sup>). Telephone participants mailed back their initial questionnaire and were then phoned to review the questionnaire and complete the short version of the Cognitive Abilities Screening Instrument (CASI-short).<sup>9</sup> A questionnaire was also mailed to an informant of each participant asking about the participant's cognitive status and functional abilities. This questionnaire included the Dementia Severity Rating Scale (DSRS),<sup>10</sup> the Functional Activities Questionnaire (FAQ),<sup>11</sup> and questions regarding Activities of Daily Living (ADL).<sup>12</sup> The FAQ and ADL sections of the questionnaire were modified to inquire about the reason (cognition, sensory, physical, or other) for the deficit or impairment on each activity. The Dementia Questionnaire (DQ) was performed if cognitive impairment was evident at the time of the visit for the in person (MMSE < 25) and telephone (CASI-short < 27) participants and for all by informant participants. The DQ is a semistructured interview completed with an informant over the telephone and has been shown to be valid and reliable in the determination of dementia.<sup>13-15</sup> Written informed consent was obtained from participants or surrogates of those examined in person and verbally from all other participants or their surrogates. The Institutional Review Board of the University of California, Irvine, approved all procedures.

**Determination of dementia.** The determination of cognitive status used the available information in the following order: neurologic examination, MMSE, CASI-short, DQ, and DSRS/FAQ/ADL questionnaire. Thus, if a participant had a neurologic examination, cognitive status was determined by the examination only; if the participant had no neurologic examination but had an MMSE score, then the cognitive status determination was based on the MMSE only; and so on.

The structured neurologic examination included mental status testing covering multiple domains and selected items regarding function. The neurologic examiner used these to assign a diagnosis of dementia according to *Diagnostic and Statistical Manual of Mental Disorders*, 4th edition (DSM-IV) criteria for dementia.<sup>16</sup> See Whittle et al.<sup>17</sup> for more details about procedures, diagnosis, and normative data in this cohort. The age- and education-specific MMSE cut scores used to identify dementia

have been shown to have good sensitivity (0.80–0.94) and specificity (0.76–0.96) in this population.<sup>18</sup> A CASI-short score  $\leq 25$  was selected as the cut score for dementia from the sample most similar to ours in terms of age and education of the two US samples used to validate the original instrument.<sup>9</sup> This cut score had good sensitivity (0.85) and specificity (0.81) for dementia when compared to a multidisciplinary diagnostic consensus conference in a subset of our cohort (unpublished data).

Computer algorithms were used to apply DSM-IV criteria for dementia to the DQ and the DSRS/FAQ/ADL questionnaire. The DQ algorithm assigned a diagnosis of dementia if at least one memory item, at least one item for another sphere of cognition, and at least one item from functional impairment were endorsed. This algorithm was found to have good sensitivity and specificity for dementia in a previous study.<sup>15</sup> The computer algorithm for the DSRS/FAQ/ADL questionnaire assigned a diagnosis of dementia if the following were true: a memory score >1, either an orientation score >1 or a judgment score >1 from the DSRS, and cognition given as the reason for requiring assistance or being dependent in any of the activities listed in the FAQ/ADL. This computer algorithm had good sensitivity (0.81) and specificity (0.89) for dementia when compared to a multidisciplinary diagnostic consensus conference in a subset of this cohort (unpublished data).

**Statistical analysis.** Prevalence was calculated for strata of sex and 2-year age categories (90–91, 92–93, 94–95, 96–97, 98–99, 100+). CI were obtained with exact binomial methods. The effects of age (5-year age categories, 90–94 and 95+), sex, and education ( $\leq$  high school, vocational school to college degree, graduate school) on the prevalence of all-cause dementia were assessed with logistic regression models. All analyses were done using SAS 9.1 and STATA 7.0 for Windows.

**RESULTS** Of the 941 participants in The 90+ Study a determination of cognitive status was possible in 911. Baseline characteristics for these are shown in table 1. The sample was mostly women (77%), Caucasian (99%), with an average age of 94 years (range = 90–106). The age distribution for men and women was almost identical (men: average = 94.2, range = 90–105; women: average = 94.5, range = 90–106). The majority of participants lived at home (56%) and the remaining lived in a nursing home (16%) or other group quarters (28%). Table 1 also shows the number of people according to each different source of information to determine cognitive status. Cognitive status was determined from an in-person evaluation (neurologic examination or MMSE) on 46% of participants (55% of men and 43% of women), from the phone CASI-short on 18% of participants (12% of men and 19% of women), and from information provided by an informant on 36% of participants (33% of men and 37% of women).

Overall, 375 participants were determined to have dementia at baseline, resulting in an overall prevalence of all-cause dementia in 90+-year-olds of 41.2% (95% CI = 38.0–44.4). The overall prevalence for men was lower (27.6%, 95% CI = 21.7–

Table 1		Baseline characteristics of participants: The 90+ Study	
Characteristic	No.	(%)	
<b>Sex</b>			
Men	210	(23)	
Women	701	(77)	
<b>Age category, y</b>			
90-91	186	(20)	
92-93	242	(27)	
94-95	204	(22)	
96-97	120	(13)	
98-99	72	(8)	
100+*	87	(10)	
<b>Education†</b>			
≤High school	272	(30)	
Vocational school to college degree	459	(51)	
Any graduate school	172	(19)	
<b>Living situation‡</b>			
Living alone	256	(28)	
In household with relatives or caregiver	255	(28)	
Group quarters	256	(28)	
Nursing home	131	(16)	
<b>Baseline cognitive status</b>			
No dementia	536	(59)	
Dementia	375	(41)	
<b>Source of dementia status determination</b>			
Neurological examination	375	(41)	
MMSE	43	(5)	
Phone CASI-short	162	(18)	
Dementia Questionnaire	257	(28)	
DSRS/FAQ/ADL Questionnaire	74	(8)	

\*For the 100+ age category the median age is 101 and maximum age is 106.

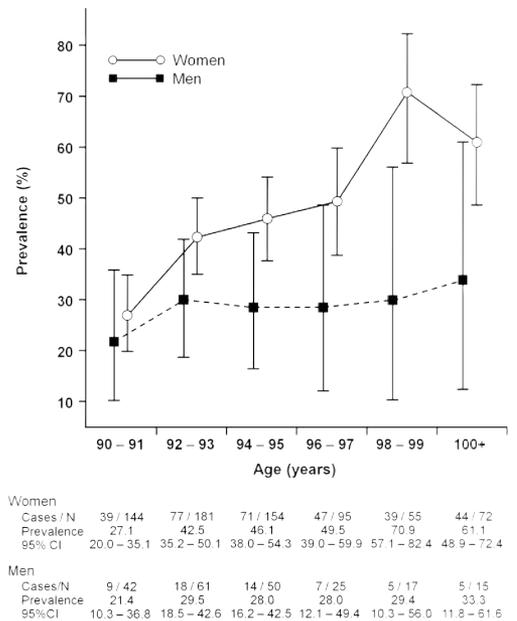
†Excludes 8 participants with missing education information.

‡Excludes 13 participants with missing living situation information.

MMSE = Mini-Mental State Examination; CASI = Cognitive Assessment Screening Instrument; DSRS = Dementia Severity Rating Scale; FAQ = Functional Activities Questionnaire; ADL = Activities of Daily Living.

34.2) than for women (45.2%, 95% CI = 41.5–49.0). The figure shows age- and sex-specific prevalence and 95% CIs. Prevalence was significantly higher for women than men in most of the age groups examined. In addition, prevalence across age categories was fairly stable for men but increased with age for women. The disparity of prevalence across age categories for men and women was confirmed by the logistic regression results (table 2) where the odds of dementia doubled every 5 years for women (OR = 2.05,  $p < 0.001$ ) but not for men

**Figure** Age- and sex-specific prevalence of all-cause dementia in The 90+ Study



(OR = 1.19,  $p = 0.58$ ). Education was significantly associated with prevalence in women but not men. Specifically, compared with women with a high school education or less, the odds of having dementia were estimated as 36–45% lower among women with more education. When comparing overall prevalence between sexes, women had almost twice the odds of having dementia compared with men (OR = 1.97,  $p < 0.001$ ).

A comparison of the 418 participants who were diagnosed through in-person procedures (i.e., neurologic examination or MMSE) with the 493 who were diagnosed through other procedures (i.e., CASI-short, DQ, or DSRS/FAQ/ADL questionnaire) revealed several differences. Participants not evaluated in person were on average older (95 vs 94,  $p < 0.001$ ), more likely to be women (81% vs 72%,  $p < 0.01$ ), less educated ( $p < 0.001$ ), and less likely to live independently ( $p < 0.001$ ). More had had falls in the previous year (56% vs 47%,  $p < 0.001$ ) and used gait-assisting devices (77% vs 64%,  $p < 0.001$ ). They (or their informants) were also more likely to report medical histories such as stroke, TIA, anxiety, or depression (all  $p < 0.05$ ). We also estimated prevalence separately for these two groups (table 3). As seen, dementia prevalence was higher among participants who were diagnosed with procedures not administered in person compared to those diagnosed through in-person procedures. Prevalence for men seen in person was estimated at 18% whereas for men not seen in person it was 39% ( $p < 0.001$ ). Similarly, prevalence for women seen in person was 39%

**Table 2** Estimated ORs for prevalent all-cause dementia in The 90+ Study

Variable	All (n = 903)*		Men (n = 210)		Women (n = 693)*	
	OR (95% CI)†	p Value	OR (95% CI)†	p Value	OR (95% CI)†	p Value
<b>Age, y</b>						
90–94	1.00 (reference)	—	1.00 (reference)	—	1.00 (reference)	—
95+	1.84 (1.40–2.42)	<0.001	1.19 (0.64–2.22)	0.58	2.05 (1.50–2.79)	<0.001
<b>Education</b>						
≤High school	1.00 (reference)	—	1.00 (reference)	—	1.00 (reference)	—
Vocational school to college degree	0.69 (0.51–0.95)	0.02	0.97 (0.45–2.10)	0.94	0.64 (0.46–0.91)	0.01
Any graduate school	0.64 (0.42–0.96)	0.03	1.01 (0.45–2.28)	0.98	0.55 (0.34–0.89)	0.01
<b>Sex</b>						
Men	1.00 (reference)	—	—	—	—	—
Women	1.97 (1.39–2.79)	<0.001	—	—	—	—

\*Excludes 8 participants with missing education information.

†From logistic regression including age, education, and sex as covariates.

‡From logistic regression including age and education as covariates.

whereas for women not seen in person it was 50% ( $p = 0.002$ ).

We were concerned that the observed sex differences in dementia prevalence could be due to differences in the source of dementia determination (in person, telephone, informant), because sex was related to source of dementia status determination ( $p < 0.01$ ). To explore this, we performed additional analyses that included source of dementia determination in the overall logistic regression analysis presented in table 2. We found that after adjustment for source of dementia determination, age and sex were still significantly related to the prevalence of dementia ( $p < 0.001$ ) and the OR changed only slightly from that given in table 2. We concluded that source of dementia determination is unlikely to explain the observed differences in prevalence between men and women.

There were no differences in age or gender between the 240 participants who were excluded from the study (210 not recruited and 30 without enough information to determine cognitive status) and the 911 participants included in the study. For those excluded, the average age as of January 1, 2003, was 93.4 years, whereas for those included it was 93.6 ( $p = 0.63$ ). Of the participants excluded, 80% were women compared to 77% of those included ( $p = 0.33$ ).

**DISCUSSION** Our findings suggest that dementia prevalence increases past age 90 for women, but remains stable for men. Prevalence for women ranged between 27% in those aged 90–91 to 71% in those aged 98–99, whereas for men it ranged from 21% in the younger age groups to 33% in those aged 100+. In addition, women with a higher educational attain-

**Table 3** Age- and sex-specific prevalence estimates according to source of dementia status determination

Age, y	In person*		Not in person*	
	Cases/N	Prevalence (95% CI)	Cases/N	Prevalence (95% CI)
<b>Men</b>				
90–94	14/81	17.3 (9.8–27.3)	21/52	40.4 (27.0–54.9)
95+	7/34	20.6 (8.7–37.9)	16/43	37.2 (23.0–53.3)
<b>Total</b>	21/115	18.3 (11.7–26.5)	37/95	38.9 (29.1–49.5)
<b>Women</b>				
90–94	57/183	31.1 (24.5–38.4)	89/209	42.6 (35.8–49.6)
95+	60/120	50.0 (40.7–59.3)	111/189	58.7 (51.4–65.8)
<b>Total</b>	117/303	38.6 (33.1–44.4)	200/398	50.3 (45.2–55.3)

\*In-person includes participants diagnosed from a neurologic examination or a Mini-Mental State Examination.

\*Not in person includes participants diagnosed from a Cognitive Assessment Screening Instrument-Short Version, a Dementia Questionnaire, or the Informant Questionnaire that combines information from the Dementia Severity Rating Scale, Functional Activities, and Activities of Daily Living.

ment had a lower dementia prevalence than less educated women.

Most prevalence studies examining sex in the oldest-old have generally found a higher prevalence for women than for men.<sup>2-4,19-21</sup> An exception is the Rotterdam Study where prevalence was similar among men and women aged 90 and older.<sup>22</sup> Most studies also report prevalence increasing between ages 90 and 94 and 95+,<sup>2-4,19</sup> with the one exception being the Berlin Aging Study, which found identical prevalence in both age categories.<sup>5</sup> Thus, our study is consistent with most studies in showing higher prevalence estimates in women than men and increasing prevalence with age.

Given these differences in prevalence by age and sex, it is desirable to have sex-specific prevalence estimates that divide 90+ participants into multiple age categories. Only a handful of studies have published such estimates: a study of all 85+ inhabitants of Leiden, The Netherlands,<sup>19</sup> the Canadian Study of Health and Aging (CSHA),<sup>2</sup> a study of all oldest-old inhabitants in two areas in central Stockholm, Sweden,<sup>3</sup> and the Leipzig Longitudinal Study of the Aged (LEILA 75+) in Germany.<sup>4</sup> Figure e-1 on the *Neurology*<sup>®</sup> Web site at [www.neurology.org](http://www.neurology.org) shows age- and sex-specific prevalence, 95% CIs, and sample size for these four studies as well as The 90+ Study. The number of subjects aged 90 and older in the previous four studies range from 119 to 502. Our age- and sex-specific estimates in The 90+ Study are based on 911 participants, providing a larger sample than previous studies that report prevalence of dementia in the oldest-old.

Although most of these studies report an increase in prevalence between age 90–94 and 95+ among women, most studies do not include enough participants for the increases to be statistically significant<sup>3,4,19</sup> (figure e-1). The only exception is the CSHA, where prevalence increased significantly from 44% in women aged 90–94 to 57% in women aged 95+.<sup>2</sup> Among men, studies are discrepant (figure e-1). The CSHA<sup>2</sup> found that prevalence increased with age, the Stockholm study<sup>3</sup> and the Leiden study found prevalence to remain stable with age,<sup>19</sup> and the LEILA 75+ study found six dementia cases in men aged 90–94 but none among those aged 95+.<sup>4</sup> The present study had enough participants to find that dementia prevalence significantly increases past age 90 in women but not in men.

It is important to note that although our prevalence estimates are fairly consistent with other studies, our study applied DSM-IV criteria whereas the four previously cited studies in the oldest-old used either DSM-III<sup>23</sup> or DSM-III-R criteria.<sup>24</sup> There is evidence that using different criteria can lead to dif-

ferent estimates of dementia prevalence,<sup>25</sup> with higher estimates obtained when using DSM-III compared to DSM-III-R or DSM-IV criteria. Thus, the use of different criteria can make direct comparisons between studies difficult.

The difference by sex found in our study has several potential explanations. Women may have sex-specific risk factors for dementia that increase with very old age or risk factors for dementia may have a greater effect in women over 90 than in men, leading to a higher incidence of dementia. Additionally, perhaps the stabilization of dementia prevalence in men is due to a stabilization of dementia incidence. The few men who reach age 90 and beyond may be “survivors” with fewer risk factors for developing dementia, suggesting that the incidence of dementia does not increase (or may even decrease) for men over 90, which has been previously noted.<sup>26,27</sup>

It is also possible that the stabilization of prevalent dementia in men is not due to a change in incidence but to shorter duration of dementia in men. Men and women may have similar dementia incidence but women may survive longer with dementia than men, resulting in higher dementia prevalence. A shorter survival among men with dementia compared with women with dementia has been previously reported in participants under age 90 by several other studies.<sup>28,29</sup> Elderly men in the general population have shorter survival than women regardless of disease and this seems to be also true in the presence of dementia.<sup>30</sup> In addition, studies of centenarians have suggested that only very fit and healthy men escape disease and reach very old age because men are more likely than women to die from potentially lethal diseases.<sup>31</sup>

To differentiate between the possibilities accounting for the sex differences in prevalence estimates, direct measurement of dementia incidence in The 90+ Study cohort is needed. Our initial estimates suggest that incidence rates of dementia are similar in women and men and that rates increase with age in both sexes.<sup>32</sup> Thus it appears that our sex differences in prevalence of all-cause dementia are due to difference in survival of men and women with dementia rather than differences in dementia incidence.

The results from The 90+ Study show that prevalence of dementia decreased with greater levels of education in women, but not men, a result previously observed in people younger than 90.<sup>33</sup> This unusual sex difference could have a variety of explanations. Low education levels might increase survival in women with dementia but not men with dementia, affecting prevalence values. Another explanation may be that, in this age group, women who attained a higher education may be different from

men who accomplished the same. For example, a 90-year-old woman in the study would have likely obtained her advanced degree in the 1930s. A woman with an advanced degree in this era would likely have a variety of risk factors different from a man, including socioeconomic status, intelligence, health care, and nutrition.

A limitation of our study is the different methods used for diagnosing dementia (i.e., neurologic examination, MMSE, CASI-short, and informant questionnaires). Although ideally we would have preferred to diagnose everyone with an in-person evaluation, this was not possible with many of the participants in The 90+ Study cohort. Some participants, or their relatives on their behalf, did not agree to an in-person examination for reasons including being frail, too cognitively impaired, or residing out of state, whereas others died before we were able to examine them, requiring us to rely on informant questionnaires. While diagnostic methods for these participants may not be ideal, excluding these participants would have resulted in an underestimate of prevalence since these participants represented a less healthy subset of the oldest-old and included a higher proportion of participants with dementia. It is possible that the higher prevalence in this group may have been due to inaccuracies of our diagnostic methods rather than a true higher prevalence. However, when we compared prevalence diagnosed by in-person methods vs not in-person methods on a subsample of participants (data not shown), 81% of participants had the same diagnosis and most discrepancies went in the opposite direction, with in-person methods diagnosing dementia more often than not in-person methods. Thus, it is unlikely that higher dementia prevalence in the group not seen in person was due to differences in methodology but rather due to true differences in prevalence. Furthermore, our overall estimates are consistent with those of the few previous studies of the oldest-old attesting to the adequacy of our ascertainment methods.

We chose to report all-cause dementia, rather than specific etiologies of dementia, for several reasons. First, in some instances we did not have enough information to specify a cause of dementia. Second, diagnostic criteria for different dementias in this cohort are not clearly established. For example, National Institute of Neurological and Communicative Disorders and Stroke–Alzheimer’s Disease and Related Disorders Association<sup>34</sup> criteria for AD specifies that it applies only to people under 90 years of age. Third, preliminary results from pathologic evaluations in this cohort suggest that about half of the participants with dementia who come to autopsy do

not have sufficient pathology to account for their dementia.<sup>35</sup>

The 90+ Study is a predominantly white population with relatively high education and socioeconomic level, characteristics that could affect the generalizability of our results. Census figures from 2000<sup>36</sup> show that 90% of 90+-year-olds in Orange County, CA, and 89% of 90+-year-olds in the United States were Caucasian. In addition, about 76% of 90+-year-olds in the United States were female. Thus, despite the modest representation of minority subjects in this cohort (1%), the composition of The 90+ Study cohort reflect the current composition of 90+-year-olds in the county and the United States. Furthermore, since high education and socioeconomic level have been associated with lower prevalence of dementia,<sup>37,38</sup> our prevalence estimates could represent underestimates of the true dementia prevalence in the oldest-old.

The 90+ Study is one of very few studies to examine prevalence in the oldest-old with enough participants ( $n = 911$ ) to allow for analysis by age and sex and for precise prevalence estimates with smaller CIs (figure e-1). Our study suggests that the prevalence of dementia is quite high for the oldest-old and in women, specifically, continues to increase past age 90. These high estimates imply that as the number of people in this age group increases, dementia will become a greater public health problem in terms of the number of people with the disease and the amount of money necessary for their care.<sup>39</sup>

## ACKNOWLEDGMENT

The authors thank all study participants and their relatives and acknowledge the valuable work of the neurologic examiners, neuropsychological testers, and staff of The 90+ Study.

*Received August 10, 2007. Accepted in final form December 7, 2007.*

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*Neurology* 2008;71;337-343 Published Online before print July 2, 2008

DOI 10.1212/01.wnl.0000310773.65918.cd

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