

# Functional Transitions and Active Life Expectancy Associated With Alzheimer Disease

Hiroko H. Dodge, PhD; Changyu Shen, BS; Rajesh Pandav, MBBS, MPH; Steven T. DeKosky, MD; Mary Ganguli, MD, MPH

**Context:** The concept of active life expectancy, the number of years a person can expect to live without disability, is used for the first time, to our knowledge, to examine the effect of Alzheimer disease (AD) on total life expectancy with different degrees of disability.

**Objectives:** To estimate and compare total life expectancy and average duration lived with different degrees of disability, between persons with and without AD.

**Design:** Ten-year prospective epidemiologic study.

**Setting:** A largely blue-collar rural community in Southwestern Pennsylvania.

**Participants:** A population-based cohort of 1201 subjects (at the beginning of follow-up) with a mean age of 75 years.

**Main Outcome Measures:** At age 70 and every 2 years thereafter, among persons with AD and nondemented per-

sons, (1) the total expectancy of remaining life and (2) the duration lived with different numbers of impaired instrumental activities of daily living (IADLs), grouped as 0 to 1, 2 to 5, and 6 to 7 impairments.

**Results:** Alzheimer disease greatly shortened the total life expectancy to a similar extent in men and women, with the most pronounced reduction among those who were younger. Besides their shorter survival, men and women with AD spent more absolute years, and also a greater proportion of their remaining lives, with 6 to 7 IADL impairments than did their nondemented age peers. Nondemented women spent more years with 2 to 5 IADL impairments than nondemented men, while women with AD spent more years with 6 to 7 IADL impairments than men with AD.

**Conclusion:** The concept of active life expectancy adds a useful new dimension to the study of outcomes in AD.

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From the Department of Epidemiology (Drs Dodge and Ganguli), the Department of Biostatistics, University of Pittsburgh Graduate School of Public Health (Mr Shen); the Division of Geriatrics and Neuropsychiatry, Department of Psychiatry (Drs Pandav, DeKosky, and Ganguli), and the Department of Neurology and Alzheimer's Research Center (Dr DeKosky), University of Pittsburgh School of Medicine, Pittsburgh, Pa.

AS THE population ages, Alzheimer disease (AD) and other dementias raise growing public health concerns because of their progressive and devastating effects on affected individuals as well as substantial caregiver burden and health care expenditures. Independent living becomes progressively more difficult for patients with AD because their cognitive impairment interferes with basic activities of daily living (ADL) and instrumental ADLs (IADLs).<sup>1-8</sup> Since AD also increases risk of mortality,<sup>9-15</sup> affected individuals are expected to have shorter lives, lived with greater disability, than their age peers.

Active life expectancy (ALE) is the number of years a group of people can expect on average to live without disability. The concept of ALE is typically used by demographers to measure health and functional status and change thereof in large

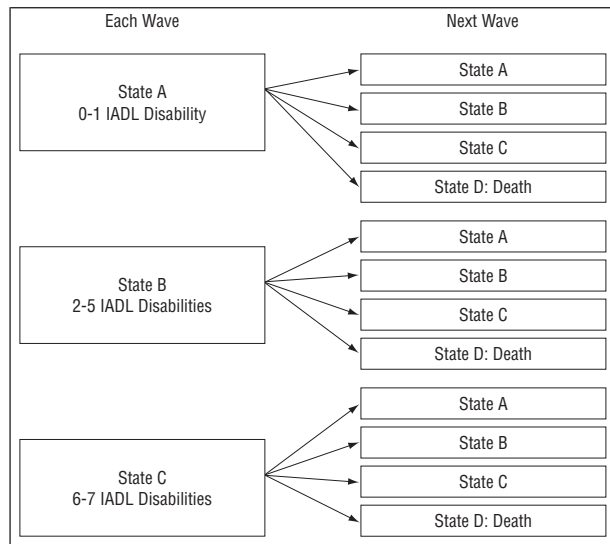
national surveys.<sup>16-22</sup> To our knowledge, ALE has not previously been used to examine the effect of specific disorders on life expectancy with different states of disability.

We examined the duration of expectancy of remaining life with different levels of disability among persons with AD compared with nondemented older adults in a representative community sample. Our data are derived from more than 10 years of follow-up in a community-dwelling elderly cohort, including those institutionalized during follow-up.

## METHODS

### STUDY DESIGN AND SAMPLE

The Monongahela Valley Independent Elders Survey (MoVIES) was a prospective epidemiologic study of dementia that began in 1987. Located in a mostly rural area of Southwestern



Twelve transitions estimated. IADL indicates instrumental activities of daily living. See "Outcome Variables: 3 Levels of Disability and Death" subsection of the "Methods" section for explanation of States A through C.

Pennsylvania, formerly home to the steel industry, the population is largely blue-collar and of mostly European descent, with low rates of in- and out-migration. The study cohort was an age-stratified random sample of 1422 persons and 259 volunteers from the same area, for a total sample size of 1681. The cohort was assessed at study entry and reassessed on average every 2 years in a series of data collection waves. Entry criteria, further details of sampling, recruitment, and screening have been reported previously.<sup>23-25</sup> Most of the attrition between successive waves was due to death (9%-14%) and less for other reasons, such as dropout and relocation (average, 2.8%).

At each wave, after providing written informed consent, subjects underwent an in-home interview, including cognitive screening and self-report data on demographic characteristics and IADL abilities, among other variables. Several of the variables, including IADL ability, were measured at each wave starting with wave 2. Therefore, this article is based on data from waves 2 through 5, from which we have complete data, including date of death confirmed by death certificates.<sup>26</sup> Approval was received annually from the University of Pittsburgh institutional review board (Pittsburgh, Pa).

#### OUTCOME VARIABLE: 3 LEVELS OF DISABILITY AND DEATH

Instrumental activities of daily living ability was assessed using the Older Americans Resources and Services questionnaire,<sup>27</sup> which asks about the ability to perform 7 activities: using the telephone, getting to places outside of walking distance, shopping for groceries (assuming the subject has transportation), preparing meals, doing housework, taking medications, and handling money. Information was obtained by self-report from study participants except when another informant was considered more reliable. Participants were regarded as having disability on each IADL item if they were reported as partly (ie, requiring help) or completely unable to perform the task independently. We categorized disability into 3 categories: no/minimal disability (0-1 impairment, state A), intermediate disability (2-5 impairments, state B), and extensive disability (6-7 impairments, state C), in addition to death (state D). The selected cut points of 6 and 2 IADL impairments on the 0 to 7 scale represented the worst 1st percentile and 10th percentile, respectively, of the cohort at wave 2, the baseline wave for these

analyses. We used impairment in IADLs rather than in basic self-care ADLs as our measure of disability for these analyses because IADL impairments typically precede basic ADL impairments in AD and are more specific to dementia.

#### PREDICTOR VARIABLE: AD

Diagnoses of dementia and AD were based on a multistage case-ascertainment process. At baseline and each follow-up, all participants were screened with a cognitive test battery described previously,<sup>25,28</sup> incorporating the neuropsychologic panel of the Consortium to Establish a Registry for Alzheimer Disease.<sup>29</sup> Clinical (diagnostic) assessment, blind to the screening data, was offered to all subjects who met operational definitions for "cognitive impairment" at any wave, and for "cognitive decline" between waves, as described previously, and also to a matched sample of "unimpaired" controls selected at baseline.<sup>25,28</sup> Clinical assessment followed a standardized protocol to determine the presence or absence of dementia according to the *Diagnostic and Statistical Manual of Mental Disorders, Revised Third Edition*<sup>30</sup>; stage of dementia according to the Clinical Dementia Rating,<sup>31</sup> and probable cause of dementia (probable AD, possible AD, or other) according to National Institute of Neurological and Communicative Disorders and Stroke and Alzheimer's Disease and Related Disorders Association criteria<sup>32</sup> and the Consortium to Establish a Registry for Alzheimer Disease protocol for non-AD dementias.<sup>33,34</sup> For the analyses reported here, a diagnosis of AD refers to a clinical diagnosis of either probable AD or possible AD, according to National Institute of Neurological and Communicative Disorders and Stroke and Alzheimer's Disease and Related Disorders Association criteria.<sup>32</sup> A subject's AD status at a given wave was determined in reference to using the estimated date of onset of AD. Since the comparisons of interest were between subjects with AD and nondemented subjects, the relatively few subjects with non-AD dementias were excluded.

#### MODEL SPECIFICATIONS

For these analyses, we examined transitions among 3 levels of disability, treating death as a fourth level. Specifically, we examined the 12 transitions between successive waves during intervals of approximately 2 years (**Figure**).

Thus, our approach captures all possible transitions, including improvements, in disability levels. First, we fit multinomial logistic regression models with 3 logits as the outcome:  $\ln(P_B/P_A)$ ,  $\ln(P_C/P_A)$ , and  $\ln(P_D/P_A)$ , with  $P_A$  indicating the probability of being at state A in 2 years;  $P_B$ , the probability of being at state B in 2 years;  $P_C$ , the probability of being at state C in 2 years; and  $P_D$ , the probability of being dead [state D] in 2 years).

For these models, we combined each subject's wave-to-wave transitions, assuming that each subject's transition followed the Markov property. The main covariates were age (continuous variable), sex, education (<high school education vs high school or greater education), subject status (volunteer vs random sample), AD status, and disability (IADL) status before the transition. Predictor status (age, AD status, and disability status) was defined at the starting point of each spell. Outcome status (disability level or death) was defined at the end point of each spell. We added all potential combinations of 2-term interaction terms into the main effect models and retained all the significant interaction terms at  $\alpha = .05$ . The final multiple logit models we estimated were:

$$\begin{aligned} \ln(P_k/P_A) = & \beta_{0k} + \beta_{1k} * \text{age} + \beta_{2k} * \text{female} + \beta_{3k} * \text{edu} + \beta_{4k} * \text{AD} \\ & + \beta_{5k} * \text{disB} + \beta_{6k} * \text{disC} + \beta_{7k} * \text{sub} + \beta_{8k} * \text{age}^3 \\ & + \beta_{9k} * \text{age} * \text{disB} + \beta_{10k} * \text{age} * \text{disC} + \beta_{11k} * \text{age}^3 * \text{disB} \\ & + \beta_{12k} * \text{age}^3 * \text{disC} + \beta_{13k} * \text{female} * \text{age} + \beta_{14k} * \text{AD} * \text{sub} \end{aligned}$$

**Table 1. Distribution of Functional Disability and Death Across Waves 2-5**

|                                    | IADLs Impaired     |                    |                   | Deceased          | Total               |
|------------------------------------|--------------------|--------------------|-------------------|-------------------|---------------------|
|                                    | 0-1                | 2-5                | 6-7               |                   |                     |
| <b>Status at Wave 3 (n = 1201)</b> |                    |                    |                   |                   |                     |
| IADLs impaired at wave 2           |                    |                    |                   |                   |                     |
| 0-1                                | 910 (97.3)         | 73 (54.1)          | 9 (24.3)          | 51 (54.3)         | <b>1043 (86.8)</b>  |
| 2-5                                | 23 (2.5)           | 60 (44.4)          | 19 (51.4)         | 31 (33.0)         | <b>133 (11.1)</b>   |
| 6-7                                | 2 (0.2)            | 2 (1.5)            | 9 (24.3)          | 12 (12.8)         | <b>25 (2.1)</b>     |
| <b>Total</b>                       | <b>935 (100.0)</b> | <b>135 (100.0)</b> | <b>37 (100.0)</b> | <b>94 (100.0)</b> | <b>1201 (100.0)</b> |
| <b>Status at Wave 4 (n = 1015)</b> |                    |                    |                   |                   |                     |
| IADLs impaired at wave 3           |                    |                    |                   |                   |                     |
| 0-1                                | 765 (97.5)         | 41 (44.6)          | 14 (28.0)         | 53 (60.2)         | <b>873 (86.0)</b>   |
| 2-5                                | 20 (2.6)           | 50 (54.4)          | 21 (42.0)         | 22 (25.0)         | <b>113 (11.1)</b>   |
| 6-7                                | 0                  | 1 (1.1)            | 15 (30.0)         | 13 (14.8)         | <b>29 (2.9)</b>     |
| <b>Total</b>                       | <b>785 (100.0)</b> | <b>92 (100.0)</b>  | <b>50 (100.0)</b> | <b>88 (100.0)</b> | <b>1015 (100.0)</b> |
| <b>Status at Wave 5 (n = 842)</b>  |                    |                    |                   |                   |                     |
| IADLs impaired at wave 4           |                    |                    |                   |                   |                     |
| 0-1                                | 616 (99.4)         | 57 (57.6)          | 14 (48.3)         | 46 (48.9)         | <b>733 (87.1)</b>   |
| 2-5                                | 4 (0.6)            | 40 (40.4)          | 11 (37.9)         | 20 (21.3)         | <b>75 (8.9)</b>     |
| 6-7                                | 0                  | 2 (2.0)            | 4 (13.8)          | 28 (29.8)         | <b>34 (4.0)</b>     |
| <b>Total</b>                       | <b>620 (100.0)</b> | <b>99 (100.0)</b>  | <b>29 (100.0)</b> | <b>94 (100.0)</b> | <b>842 (100.0)</b>  |

Abbreviation: IADLs, instrumental activities of daily living.

where  $k=B, C, D$ ; edu, high school education or greater; dis, disability levels of each state at previous wave; and sub, volunteer vs random sample. Here, state A (no/minimal disability) is the baseline, and for each of the odds of state  $k$  to A ( $k=B, C, D$ ), there is a set of parameters to be estimated. That is, 3 logits are simultaneously estimated by using the maximum likelihood estimation.

As stated in the "Results" section, those excluded from our analysis because of missing data differed significantly in certain variables from those included in the analysis, suggesting that our "missingness" pattern was at least missing at random (MAR).<sup>35</sup> We conducted a post hoc analysis assuming that our missingness pattern is nonignorable where missingness depends on unobserved data. We performed a weighted logistic regression<sup>36</sup> to adjust for bias. Since our main finding in the weighted analysis did not differ from the results of the original unweighted analysis, we present only the results of the unweighted method in this article. The estimated coefficients of the above models were used for calculating the transitional probabilities among each stage. Based on these transitional probabilities, we constructed increment-decrement life tables, starting from age 70 years. The initial distribution of the number of people at each state was calculated based on cross-sectional multinomial logistic regression at wave 2.

## RESULTS

At wave 2, there were 1342 participants. Among them, 1134 and 973 also participated at waves 3 and 4, respectively. We excluded 19, 28, and 25 cases of non-AD dementias at waves 2, 3, and 4, respectively, and 13, 5, and 5 subjects with missing IADL information at waves 2, 4, and 5, respectively. We further deleted observations with missing outcome data, including (1) those who skipped the subsequent wave but then returned to the study (24, 19, and 22 subjects at waves 3, 4, and 5, respectively); (2) those who skipped the subsequent wave and then died, outside the 2-year window (50, 47, and 52 subjects at waves 3, 4, and 5, respectively); and (3) those who

**Table 2. Characteristics at the Beginning of Each Observation Period**

|                                       | Wave 2<br>(n = 1201) | Wave 3<br>(n = 1015) | Wave 4<br>(n = 842) |
|---------------------------------------|----------------------|----------------------|---------------------|
| Age, mean (SD), y                     | 74.9 (5.5)           | 76.6 (5.2)           | 78.4 (4.9)          |
| % Women                               | 62.0                 | 63.3                 | 65.0                |
| % With high school education and over | 60.6                 | 62.0                 | 64.5                |
| % With Alzheimer disease              | 7.2                  | 9.6                  | 11.4                |

dropped out of the study at the subsequent wave (35, 20, and 27 subjects at waves 3, 4, and 5, respectively). The final number of observations for each wave-to-wave transition were, therefore, 1201, 1015, and 842, respectively. **Table 1** presents the number of participants followed up at wave 2 and thereafter and their IADL transitional patterns.

We compared characteristics for the 3058 observations included in, and 296 observations excluded from, the analyses. Excluded participants were significantly older (mean age, 78.3 vs 76.4 years; Wilcoxon rank sum test, 1 *df*,  $P < .001$ ), less educated (proportion of high school education and over: 55.4% vs 62.1%;  $\chi^2_1$  test,  $P = .02$ ), and more likely to have AD (proportion of AD; 21.6% vs 9.1%;  $\chi^2$  test, 1 *df*,  $P < .001$ ). However, those included and excluded had similar sex distributions (59.8% vs 63.3% female;  $\chi^2$  test, 1 *df*,  $P = .26$ ).

**Table 2** presents the mean (SD) age and the proportions of women, of subjects with less than high school education, and of those with AD at the beginning of each observation period (eg, at wave 2 for the wave 2-3 transition). Results of the multinomial logit models and the transitional probabilities are available from the first author on request.

**Table 3. Life Expectancy of Men With Alzheimer Disease (AD) vs Nondemented Men at Different Ages With Different Levels of IADL Disability**

| Age, y | 1997 US Total Life Expectancy (White Males) | Remaining Life Spent at Each Disability Level |                    |                    |                                |                |                   |                   |                    |                                |                | Selected Comparison AD vs Nondemented |      |
|--------|---|---|--------------------|--------------------|--------------------------------|----------------|-------------------|-------------------|--------------------|--------------------------------|----------------|---------------------------------------|------|
|        |   | Nondemented Men                               |                    |                    |                                |                | Men With AD       |                   |                    |                                |                |                                       |      |
|        |   | 0-1 Impaired IADL                             | 2-5 Impaired IADLs | 6-7 Impaired IADLs | (A) Total Remaining Life Years | Mortality Rate | 0-1 Impaired IADL | 2-5 Impaired IADL | 6-7 Impaired IADLs | (B) Total Remaining Life Years | Mortality Rate | †                                     | ‡    |
| 70     | 12.7  | 12.1 (87.9)                                   | 1.4 (10.0)         | 0.3 (2.1)          | 13.7                           | 0.038          | 5.0 (72.4)        | 0.8 (11.1)        | 1.1 (16.5)         | 6.8                            | 0.111          | -6.9                                  | 0.50 |
| 72     | 11.6  | 11.0 (86.3)                                   | 1.4 (11.3)         | 0.3 (2.4)          | 12.8                           | 0.042          | 4.3 (68.3)        | 0.8 (12.1)        | 1.2 (19.7)         | 6.3                            | 0.128          | -6.5                                  | 0.49 |
| 74     | 10.5  | 9.9 (84.4)                                    | 1.5 (12.9)         | 0.3 (2.8)          | 11.8                           | 0.046          | 3.7 (63.5)        | 0.8 (14.0)        | 1.3 (22.5)         | 5.9                            | 0.144          | -5.9                                  | 0.50 |
| 76     | 9.4   | 8.9 (82.1)                                    | 1.6 (14.8)         | 0.3 (3.1)          | 10.8                           | 0.050          | 3.2 (58.1)        | 0.9 (16.4)        | 1.4 (25.5)         | 5.5                            | 0.157          | -5.3                                  | 0.51 |
| 78     | 8.4   | 7.8 (79.1)                                    | 1.7 (17.1)         | 0.4 (3.6)          | 9.9                            | 0.055          | 2.7 (51.9)        | 1.0 (19.4)        | 1.5 (28.5)         | 5.2                            | 0.168          | -4.7                                  | 0.52 |
| 80     | 7.4   | 6.7 (75.8)                                    | 1.8 (19.9)         | 0.4 (4.3)          | 8.9                            | 0.059          | 2.2 (45.5)        | 1.1 (22.4)        | 1.6 (32.1)         | 4.8                            | 0.178          | -4.1                                  | 0.54 |
| 82     | 6.5   | 5.7 (71.7)                                    | 1.8 (23.2)         | 0.4 (5.2)          | 7.9                            | 0.064          | 1.7 (38.3)        | 1.1 (25.4)        | 1.6 (36.3)         | 4.5                            | 0.183          | -3.4                                  | 0.57 |
| 84     | 5.8   | 4.6 (66.6)                                    | 1.9 (27.2)         | 0.4 (6.3)          | 6.8                            | 0.074          | 1.2 (30.6)        | 1.1 (28.1)        | 1.7 (41.0)         | 4.1                            | 0.198          | -2.8                                  | 0.59 |
| 86     | 5.1   | 3.5 (60.1)                                    | 1.8 (31.9)         | 0.5 (7.8)          | 5.8                            | 0.091          | 0.8 (22.5)        | 1.1 (30.7)        | 1.7 (46.8)         | 3.6                            | 0.227          | -2.2                                  | 0.62 |
| 88     | 4.5   | 2.5 (52.7)                                    | 1.8 (37.4)         | 0.5 (10.0)         | 4.7                            | 0.117          | 0.4 (14.4)        | 1.0 (32.5)        | 1.6 (53.1)         | 3.1                            | 0.268          | -1.7                                  | 0.65 |
| 90     | 3.9   | 1.6 (43.5)                                    | 1.6 (43.2)         | 0.5 (13.2)         | 3.7                            | 0.166          | 0.2 (7.8)         | 0.8 (32.9)        | 1.5 (59.2)         | 2.6                            | 0.332          | -1.2                                  | 0.69 |
| 92     | 3.5   | 0.9 (33.2)                                    | 1.4 (48.7)         | 0.5 (18.4)         | 2.8                            | 0.258          | 0.1 (3.8)         | 0.7 (32.1)        | 1.3 (64.1)         | 2.1                            | 0.429          | -0.7                                  | 0.75 |
| 94     | 3.1   | 0.4 (22.0)                                    | 1.0 (51.0)         | 0.5 (27.0)         | 2.0                            | 0.421          | 0.0 (1.2)         | 0.5 (29.7)        | 1.2 (69.2)         | 1.7                            | 0.554          | -0.3                                  | 0.86 |
| 96     | 2.8   | 0.2 (11.7)                                    | 0.7 (47.6)         | 0.6 (41.4)         | 1.5                            | 0.653          | 0.0 (0.7)         | 0.4 (24.0)        | 1.1 (75.3)         | 1.5                            | 0.660          | 0.1                                   | 1.03 |
| 98     | 2.5   | 0.0 (3.4)                                     | 0.4 (35.3)         | 0.7 (61.2)         | 1.2                            | 0.859          | 0.0 (0.0)         | 0.2 (14.7)        | 1.2 (85.3)         | 1.4                            | 0.693          | 0.3                                   | 1.23 |
| 100    | 2.2   | 0.0 (0.0)                                     | 0.2 (21.5)         | 0.8 (78.5)         | 1.1                            | 0.930          | 0.0 (0.0)         | 0.1 (5.1)         | 1.3 (94.9)         | 1.4                            | 0.680          | 0.3                                   | 1.29 |
| 102    | §   | 0.0 (0.0)                                     | 0.1 (12.0)         | 0.9 (88.0)         | 1.0                            | 1.000          | 0.0 (0.0)         | 0.0 (2.0)         | 1.0 (98.0)         | 1.0                            | 1.000          | 0.0                                   | 1.00 |

Abbreviation: IADL, instrumental activities of daily living.  
 \*Data are given as number (percentage) of years unless otherwise indicated.  
 †Absolute difference in years, ie, column (B) minus column (A).  
 ‡Ratio, ie, column (B) divided by column (A).  
 §Not estimated.

**Table 4. Life Expectancy of Women With Alzheimer Disease (AD) vs Nondemented Women at Different Ages With Different Levels of IADL Disability**

| Age, y | 1997 US Total Life Expectancy (White Females) | Remaining Life Spent at Each Disability Level |                    |                    |                                |                |                   |                    |                    |                                |                | Selected Comparison AD vs Nondemented |      |
|--------|---|---|--------------------|--------------------|--------------------------------|----------------|-------------------|--------------------|--------------------|--------------------------------|----------------|---------------------------------------|------|
|        |   | Nondemented Women                             |                    |                    |                                |                | Women With AD     |                    |                    |                                |                |                                       |      |
|        |   | 0-1 Impaired IADL                             | 2-5 Impaired IADLs | 6-7 Impaired IADLs | (A) Total Remaining Life Years | Mortality Rate | 0-1 Impaired IADL | 2-5 Impaired IADLs | 6-7 Impaired IADLs | (B) Total Remaining Life Years | Mortality Rate | †                                     | ‡    |
| 70     | 15.5  | 13.4 (78.8)                                   | 3.2 (18.5)         | 0.5 (2.6)          | 17.0                           | 0.011          | 4.9 (47.2)        | 2.0 (19.7)         | 3.4 (33.1)         | 10.3                           | 0.034          | -6.8                                  | 0.60 |
| 72     | 14.1  | 11.8 (76.6)                                   | 3.1 (20.4)         | 0.5 (2.9)          | 15.4                           | 0.016          | 3.7 (41.3)        | 1.9 (21.2)         | 3.4 (37.6)         | 8.9                            | 0.052          | -6.5                                  | 0.58 |
| 74     | 12.8  | 10.3 (74.2)                                   | 3.1 (22.6)         | 0.5 (3.2)          | 13.9                           | 0.021          | 2.8 (35.5)        | 1.8 (22.8)         | 3.2 (41.5)         | 7.8                            | 0.072          | -6.1                                  | 0.56 |
| 76     | 11.5  | 8.9 (71.3)                                    | 3.1 (25.1)         | 0.5 (3.6)          | 12.4                           | 0.026          | 2.1 (30.4)        | 1.7 (24.8)         | 3.1 (44.8)         | 6.9                            | 0.094          | -5.6                                  | 0.55 |
| 78     | 10.3  | 7.5 (67.9)                                    | 3.1 (28.0)         | 0.5 (4.1)          | 11.0                           | 0.031          | 1.6 (25.7)        | 1.6 (26.9)         | 2.9 (47.4)         | 6.1                            | 0.117          | -5.0                                  | 0.55 |
| 80     | 9.1   | 6.2 (64.1)                                    | 3.0 (31.3)         | 0.4 (4.5)          | 9.7                            | 0.038          | 1.2 (21.5)        | 1.6 (29.1)         | 2.7 (49.4)         | 5.4                            | 0.141          | -4.3                                  | 0.56 |
| 82     | 8.0   | 5.0 (59.7)                                    | 2.9 (35.0)         | 0.4 (5.3)          | 8.4                            | 0.044          | 0.9 (18.1)        | 1.5 (31.1)         | 2.5 (50.7)         | 4.9                            | 0.155          | -3.5                                  | 0.58 |
| 84     | 7.0   | 3.8 (54.5)                                    | 2.8 (39.3)         | 0.4 (6.1)          | 7.0                            | 0.056          | 0.6 (14.6)        | 1.4 (33.1)         | 2.2 (52.3)         | 4.3                            | 0.177          | -2.8                                  | 0.61 |
| 86     | 6.1   | 2.8 (48.4)                                    | 2.6 (44.4)         | 0.4 (7.3)          | 5.8                            | 0.078          | 0.4 (10.4)        | 1.3 (34.9)         | 2.0 (54.5)         | 3.7                            | 0.211          | -2.1                                  | 0.64 |
| 88     | 5.3   | 1.9 (41.4)                                    | 2.3 (49.9)         | 0.4 (8.8)          | 4.6                            | 0.112          | 0.2 (6.1)         | 1.1 (36.2)         | 1.8 (57.6)         | 3.1                            | 0.257          | -1.5                                  | 0.68 |
| 90     | 4.6   | 1.2 (33.4)                                    | 1.9 (55.6)         | 0.4 (10.7)         | 3.5                            | 0.175          | 0.1 (3.5)         | 0.9 (36.6)         | 1.5 (59.8)         | 2.5                            | 0.327          | -0.9                                  | 0.73 |
| 92     | 4.0   | 0.6 (25.4)                                    | 1.5 (60.3)         | 0.4 (14.3)         | 2.5                            | 0.297          | 0.0 (2.0)         | 0.7 (36.5)         | 1.3 (61.6)         | 2.0                            | 0.433          | -0.5                                  | 0.81 |
| 94     | 3.5   | 0.3 (17.2)                                    | 1.1 (62.2)         | 0.4 (20.0)         | 1.8                            | 0.493          | 0.0 (0.6)         | 0.6 (35.4)         | 1.0 (64.0)         | 1.6                            | 0.587          | -0.2                                  | 0.89 |
| 96     | 3.1   | 0.1 (9.6)                                     | 0.8 (57.8)         | 0.4 (32.6)         | 1.4                            | 0.716          | 0.0 (0.0)         | 0.4 (31.1)         | 0.9 (68.9)         | 1.4                            | 0.731          | 0.0                                   | 1.00 |
| 98     | 2.7   | 0.0 (3.6)                                     | 0.5 (42.0)         | 0.6 (54.5)         | 1.1                            | 0.891          | 0.0 (0.0)         | 0.3 (19.8)         | 1.0 (80.2)         | 1.3                            | 0.792          | 0.1                                   | 1.13 |
| 100    | 2.4   | 0.0 (0.0)                                     | 0.2 (22.1)         | 0.8 (76.9)         | 1.0                            | 0.962          | 0.0 (0.0)         | 0.1 (6.6)          | 1.1 (92.6)         | 1.2                            | 0.804          | 0.2                                   | 1.17 |
| 102    | §   | 0.0 (0.0)                                     | 0.1 (13.0)         | 0.9 (87.0)         | 1.0                            | 1.000          | 0.0 (0.0)         | 0.0 (2.0)          | 1.0 (98.0)         | 1.0                            | 1.000          | 0.0                                   | 1.00 |

Abbreviation: IADL, instrumental activities of daily living.  
 \*Data are given as number (percentage) of years unless otherwise indicated.  
 †Absolute difference in years, ie, column (B) minus column (A).  
 ‡Ratio, ie, column (B) divided by column (A).  
 §Not estimated.

**OVERALL LIFE EXPECTANCY**

**MoVIES Cohort Nondemented Members vs US National Figures**

**Table 3** and **Table 4** present total life expectancy and average years spent at each disability level, at each age,

for men and women. For comparison, the first column in Table 3 and Table 4 presents life expectancy for the US white population in 1997.<sup>37</sup>

For example, Table 3 may be interpreted as follows: 70-year-old US white men have 12.7 years of remaining life expectancy, according to the US Census. In our study cohort, 70-year-old men without dementia had

13.7 years of remaining life (column A), while 70-year old men with AD had 6.8 years of remaining life on average (column B). These remaining years of life are disaggregated into duration spent at the 3 disability levels. Nondemented men aged 70 years spend 12.1 years with 0 to 1 disability, 1.4 years with 2 to 5 disabilities, and 0.3 years with 6 to 7 disabilities. The corresponding figures are 5.0 years, 0.8 years, and 1.1 years, respectively, for 70-year-old men with AD.

Nondemented men in our cohort had about a 1-year longer total life expectancy than the US white male population until age 84 years, after which the difference narrowed with increasing age (Table 3). The same trend was also seen for nondemented women in our cohort (Table 4), who had more than a 2-year longer life expectancy in their 70s compared with national figures, with the difference shrinking after age 80 years. As with national figures after age 94 years, men's and women's life expectancies in our cohort also became identical with increasing age.

### MoVIES Cohort Nondemented vs Persons With AD

Both men and women with AD had much shorter life expectancies than nondemented persons but the difference narrowed as they aged (Tables 3 and 4). Men and women had fairly similar AD-nondemented ratios for total life expectancy. The magnitude of the difference between the demented and nondemented subjects decreased with age.

### DURATION SPENT AT EACH DISABILITY LEVEL

#### Nondemented Participants

Among nondemented men at age 70 years, about 88% of remaining life was spent with no to minimal disability. The proportion of remaining life spent at this level shrank gradually with aging, but even at age 88 years, nondemented men spent more than half of their remaining life with no to minimal disability, 37% of it with intermediate disability, and 10% with extensive disability. By contrast, nondemented women spent more absolute years and also a higher proportion of their remaining lives with intermediate disability in their 70s and 80s compared with nondemented men. Thus, except at very old age, women's additional years of life were spent with intermediate or extensive disability.

#### Participants With AD

Among those with AD, women also lived longer in their 70s and 80s, but the gained survival was spent living with intermediate or extensive disability. Unlike nondemented persons, women with AD actually spent fewer absolute years with no to minimal disability than men with AD despite living longer. As expected, both men and women with AD spent much larger shares of their remaining life and also more absolute years with extensive disability than their nondemented age and sex peers.

### COMMENT

Previous research indicates that dementia, including AD, is strongly associated with impairment in ADLs or

IADLs.<sup>2-8</sup> Dementia is also a risk factor for mortality in a variety of population types.<sup>9-15</sup> Thus, persons with AD would be expected to live shorter lives, with a larger share of their remaining lives spent with disabilities. To our knowledge, no previous study has examined the effect of AD on remaining life spent with different levels of disability.

Here, we applied the concept of ALE to a single epidemiologic study sample. Previous community-based studies have compared the duration of ALE between men and women<sup>38</sup> and among race and education groups<sup>39</sup> to compare disability-free life expectancy with cognitive impairment-free life expectancy<sup>40</sup> and to examine the effects on ALE of smoking and physical activities,<sup>41</sup> but not of a specific disorder.

The average duration of survival with AD varies among previous reports, depending on sample selection, duration of follow-up, and the starting point for the measurement of survival (eg, date of onset of symptoms, date of diagnosis, or date of entry into study or institution<sup>15,42-55</sup>) although all agree that average survival with AD is longer among women than men. Our study is consistent with another study,<sup>56</sup> which followed incident AD cases in a community sample and found very similar mortality risk among men and women with AD in the very old ( $\geq 85$  years) group. Our findings may reflect the presence of greater comorbidity leading to earlier death among men than among women with AD,<sup>57</sup> or a more rapid progression of AD in women.<sup>58-61</sup> The inherent survival advantage of women in general may lead women to live longer, tolerating greater disability, than men.

Our data on ALE, from 10 years of follow-up of a representative community sample, show that AD greatly shortened the total life expectancy of men and women to approximately the same extent. This reduction was most pronounced among the younger members of the cohort. In addition to their shorter survival, men and women with AD spent more absolute years and a greater proportion of their remaining lives with extensive disability than did their nondemented age peers. Nondemented women spent more years with intermediate disabilities than nondemented men, while women with AD spent more years with extensive disabilities than men with AD.

Individuals with AD are a heterogeneous group. Duration of survival, overall and at each disability level, will vary depending on age at onset of dementia, comorbid conditions, genetic traits, and other risk factors associated with mortality and disability. Because ALE is a demographic approach, it does not capture these heterogeneities, but rather shows the average duration of survival, overall and with disabilities, within a specific population. While this measure of disease impact does not necessarily indicate the prognosis of the individual patient, it is useful to planners and policymakers in strategizing for resource development, for example, in estimating the needs for in-home or institutional services in local or national populations.

As regards study limitations, we recognize that disabilities in a person with AD are not entirely and necessarily caused by AD. Results from our study sample in a

particular rural area may have limited generalizability to other regions. We have relatively few subjects who survived beyond age 95 years. We used self-reported IADL measures, which some authors consider less reliable and perhaps gender-biased compared with objective assessments.<sup>62,63</sup> Our biennial follow-up design does not allow recognition of multiple functional transitions that may have occurred within each 2-year interval. For example, a recent study that adjusted for length bias<sup>64</sup> showed shorter survival duration than our or previous studies.

The concept of ALE adds an important new dimension to the study of outcomes in AD. This measurement is distinct from “dementia-free life expectancy” (years of life remaining without dementia), which was used, for example, by a European group to compare the effect of dementia on public burden among different countries.<sup>65</sup> Estimates of the public burden of disease could be enriched not only by studies on delay in onset<sup>66</sup> or duration of disease-free survival, but also by the aggregate effect of diseases on the duration of remaining life spent with varying levels of disability. Thus, the approach presented here goes beyond simple duration of survival. Depending on the purpose of the investigation, our approach could be modified using a different measure of disability, eg, basic ADLs or cognitive impairment or some combination of measures. It can also be expanded to estimate the effects of intervention trials on the progression of the disease and on the resultant delays in disability.

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Corresponding author: Hiroko Dodge, PhD, Department of Epidemiology, University of Pittsburgh, 127 Parran Hall, 130 DeSoto St, Pittsburgh PA 15261 (e-mail: [dodge@edc.pitt.edu](mailto:dodge@edc.pitt.edu)).

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