Active Life among the Elderly in the United States: Multistate Life-table Estimates and Population Projections

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THIS ARTICLE REPORTS ON RESEARCH THAT DIRECTLY assesses the elderly population's length and quality of life. Because the elderly are one of the fastest-growing subpopulations in the United States (Siegel and Taeuber 1984), health planners and policy makers must fully understand and respond to the effects of increasing size, changes in age and sex composition, and consequent changes in functional statuses of the elderly. To address such questions, we present current and future estimates of the size, age composition, and life expectancy of dependent and independent elderly male and female populations in the United States.

Through the use of longitudinal data sets and new methodological techniques, researchers have started to compute *active life expectancies*—the expected durations in years of functional well-being—which measure not only how long a subpopulation can expect to live at each age, but also what fractions of these expected remaining lifetimes will be spent in independent or dependent statuses. Estimates and projections of active life are important to an individual, because they indicate the quality as well as the quantity of years a person can expect to live beyond a given age—an important factor in individual planning for various life course events. At the societal level, such information is crucial in planning for housing, health, and social service needs.

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Researchers have employed a number of data sets and analytic techniques to explore active life. Katz et al. (1983), for example, used unistate life-table analysis to examine active life expectancies among the Massachusetts elderly, differentiating those individuals who were functionally dependent, institutionalized, or dead from those who were not. Active life expectancies, as indicated by a score calculated using four variables, were calculated for those individuals who were initially independent in their activities of daily living (ADL) and who were living in the community. The concept of ADL includes limitations in ability to carry out such functions as eating, bathing, toileting, transferring from bed to chair, maintaining continence, and dressing. Katz et al. (1983) found that active life expectancies decreased with age, from 10.0 years for the group aged 65 to 69, 8.1 years for those aged 70 to 74, and 2.9 years for those aged 85 and over. The percentage of remaining years of life that could be lived in an independent status declined from 61 percent for those aged 65 to 69 to 57 percent for those aged 70 to 74 and to 40 percent for those aged 85 and over. Moreover, although females generally live longer than men, Katz's team found men and women could expect to live the same number of years of active life.

Bebbington (1988) examined expectations of life without disability in England and Wales with cross-sectional data for 1985. He found that women at age 65 could expect to live an additional 17.5 years, of which 8.9 years would be free of disability. Similarly, men at age 65 could expect to live 13.4 years, of which 7.7 years would be free of disability. Although women lived longer than men and lived more years without a disability, they spent proportionately more time with a disability because of their longer lives. Such findings have also been found for men and women in Quebec, the rest of Canada, and France (Bebbington 1988, table 3).

Conventional or unistate methods of analysis, upon which most researchers have based their results, are deficient in that they do not deal explicitly with and may even ignore the possibility of a *return* transition from dependent to independent status. Such conventional single-decrement life tables treat transitions to a dependent status as a terminal move. Indeed, to answer the question of what is the expectation of active life of someone who is independent at age 'x' has, until now, had one constrictive assumption:

> An inherent assumption behind this question is that disability (dependence) is irreversible. In other words, people experience a span of healthy life, which is terminated by the onset of disability or death. This is a popular image of long-term disability, but probably fallacious even though there is no evidence about the rate of recovery from 'limiting long-standing illness.' However, the expectation of continuing life without disability can be calculated if we assume that disability is irreversible once someone becomes disabled, they are forever lost to the healthy population just as if they had died (Bebbington 1988, 323).

Some analysts have tried to remedy the problem of defining disability to be an absorbing state by examining transition probabilities. Manton (1988), for example, examined the transitions into and out of functionally impaired statuses. In comparing transitions by sex, he found that males and females demonstrated roughly the same probabilities of becoming disabled (incident cases), but women were more likely to be disabled (prevalent cases). These relations, combined with the longer life expectancy of females at each functional status and age, indicate that the greater prevalence of disability among females is due to their greater longevity and not a greater risk of becoming functionally disabled (Manton 1988). Although he found that individuals can demonstrate long-term functional improvements, his presentation was hindered by the mass of data within each table. Indeed, without some summarizing scheme, transitional probabilities are difficult to compare, even when disaggregated into only two or three 10-year age groups.

Multistate life-table analysis, a recently developed technique, is well suited for dealing with transitions and their summarization. For an overview and review of multistate applications, see Rogers 1980, and Schoen 1988. Multistate analysis treats dependency as a temporary rather than as an irreversible transition. Indeed, multistate life tables take into account several statuses simultaneously, allow return transitions, and permit each subpopulation under examination to experience both increments and decrements. In multistate life tables, individuals who exit a particular subpopulation (for example, by illness, marriage, or loss of job) can return to that subpopulation (for example, by recovery, divorce, or reemployment). Hence, multistate life tables are especially well suited for analyses of the evolution of active life expectancy.

Rogers, Rogers, and Branch (1989) applied multistate analysis to the

Massachusetts data set used by Katz et al. (1983), and presented the first estimates of expectations of active life across four different functional statuses of well-being, including expectations of life for those who were independent and remained independent, or, say, those who were dependent and became independent. They found that those individuals who were *independent* at age 65 could expect to live an average of 16.5 years, out of which total 14.7 would be lived in an independent status and 1.7 years in a dependent status; by age 80, those expectations dropped to 7.6, 5.6, and 1.9 years, respectively. Moreover, they showed that those individuals who were *dependent* at age 65 could expect to live an average of 15.5 additional years, 72 percent of which would be spent in active life (by transiting back to an independent status). The remaining 28 percent of their remaining lifetime would be spent in a dependent status. Thus, those who survive to older ages will spend a greater proportion of their remaining years of life in a dependent state relative to that of younger individuals. Nevertheless, even by age 80, 39 percent of the remaining time for a person then dependent can still be expected to be spent in an independent status.

Although it is necessary to take stock of the current elderly population's functional status, it is vital that health planners and policy makers anticipate the future elderly population's growth and consequent functional statuses and needs. Toward this end, figure 1 displays the projected United States population aged 70 and over, our particular designation of the "elderly." This figure graphically shows how the projected population will increase slowly from 21 million in 1990 to 25 million in 2000. This elderly population will grow slowly at the turn of the century, but then it will swell to 52.5 million in 2041. After the peak in 2041, the elderly population should slowly decline in size, reaching 51 million in 2050. This trend reflects the entrance of new cohorts of elderly. For instance, as babies born during the 1920s will reach age 70, near the turn of the century, they will provide a small rise in the elderly population. The elderly population will level off during the accession of the Depression Era babies, beginning in the year 2000, mushroom with the entry of the Baby Boom babies, beginning in 2015, and then dip with the absorption of the Baby Boomers and the entry of the Baby Bust babies. Not only is the size of the elderly population influenced by changing cohort sizes, but so is the age distribution of the elderly and of the entire population.

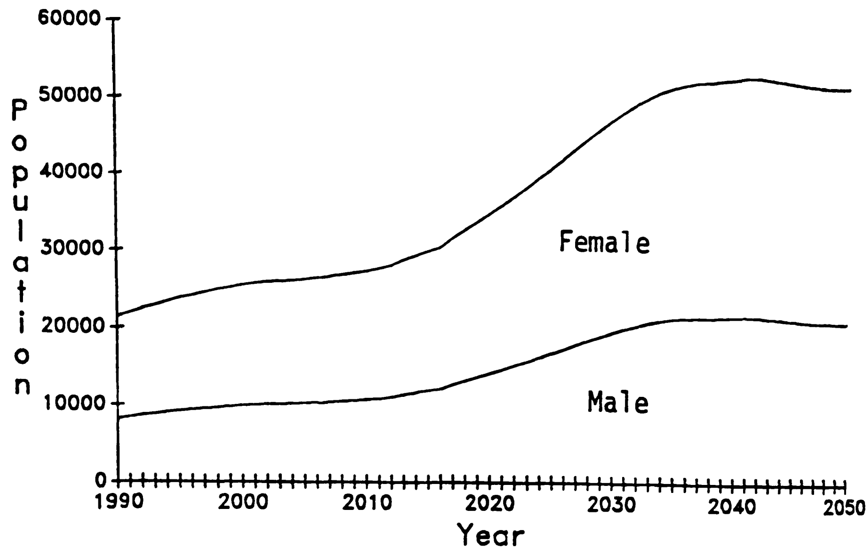


FIG. 1. Sex-specific projected population aged 70 and over: United States, 1990–2050 (population in thousands).
Source: U.S. Bureau of the Census 1989, middle series.

For example, 8 percent of the United States population will be aged 70 and over in 1990; by 2020 this fraction will increase to 12 percent; and in 2060 it is estimated that 18 percent of the population will be aged 70 and over (see table 1). The United States is currently an aged population and is projected to grow older (see Cowgill 1972, 246). Moreover, the oldest age groups are projected to be one of the fastest-growing subpopulations within the elderly population. Between 1990 and 2060 the number of individuals aged 70 to 79 are expected to increase almost two-fold, the number of those aged 80 to 89 are expected to increase almost three-fold, and the number of those aged 90 and over are expected to increase almost seven-fold. At present, only a small minority of elderly individuals (less than 6 percent) are aged 90 or more. By the year 2060, however, 15 percent of the elderly will be aged 90 and over. Therefore, we expect that, with time, the aged population will increase in number, will itself become older, and will comprise a much larger proportion of the total population.

As the elderly population increases in number, health demands are

TABLE 1
Age Composition of the Population Aged 70 and Over:
United States, 1990–2060[a]

Age category	1990	2000	2020	2040	2060
	Year				
70–79					
Number[b]	14,227	16,034	22,487	29,225	29,137
Percent[c]	66.8%	63.1%	65.0%	55.9%	54.9%
80–89					
Number[b]	5,893	7,538	8,921	17,671	15,925
Percent[c]	27.6%	29.7%	25.8%	33.8%	30.0%
90 and over					
Number[b]	1,189	1,819	3,191	5,370	8,025
Percent[c]	5.6%	7.2%	9.2%	10.3%	15.1%
Total					
Number[b]	21,309	25,391	34,599	52,266	53,087
Percent[d]	8.5%	9.5%	11.8%	17.3%	17.9%

Source: U.S. Bureau of the Census 1989, middle series.
[a] Projected.
[b] Numbers in thousands.
[c] Percentage of the population aged 70 and over.
[d] Percentage of the total population.

also expected to increase. For instance, between the years 1980 and 2040, although the total population will increase by two-fifths, the number of noninstitutionalized elderly needing assistance in one or more activities of daily living is estimated to double. This doubling is partially due to a growing population, but it is also linked to the aging of the population. Moreover, within this same time period, the number of noninstitutionalized individuals 75 years of age and over who are likely to need assistance in one or more activities of daily living is expected to quadruple (Rice and Feldman 1983). Therefore, projected estimates of the independent and dependent populations of elderly help to identify future elderly needs. And although the number of individuals who are limited in their activities will double, the number of nursing home residents will increase three and one-half times (Rice and

Feldman 1983). Such projections are useful to hospitals or nursing homes to determine the numbers, ages, and characteristics of elderly who will require their services, and to public health officials who need to make decisions on whether to initiate, continue, or modify programs that expressly address elderly needs.

Our current research contributes to past findings through our use of a relatively large and recent national probability sample, employment of multistate analysis, inclusion of three as well as two functional statuses, and calculation of population projections of tomorrow's active elderly. As such, our research is directed at determining the current and future mix of the elderly independent and dependent subpopulations within the United States. More simply, we estimate how many United States elderly live and will live independently and how many need and will need help with activities of daily living.

Data and Methods

To estimate life expectancies for the United States elderly population, we employed the data set produced by the 1986 Longitudinal Study of Aging (LSOA). This data set is current, includes a relatively large probability sample of the United States elderly, and contains all of the variables we require. The 1986 LSOA is based on participants in the 1984 Supplement on Aging (SOA). The SOA was added to the 1984 National Health Interview Survey (NHIS) and is a national probability sample of the civilian, noninstitutionalized elderly population that includes demographic, social, and health-related information on all respondents.

The SOA interviews were conducted in person by trained U.S. Bureau of the Census interviewers who were knowledgeable about census and NHIS procedures. Interviews were conducted with the respondents themselves if possible. If the respondents were unable to answer the questions in the interview, the interview was conducted with a proxy person, who almost always was a relative and who knew the sample person well. Reinterviews in the LSOA were conducted primarily through computer-assisted telephone interviews (U.S. Dept. of Health and Human Services 1988).

The 1986 LSOA reinterviewed 5,151 people who were 70 years and over in the 1984 SOA. Because the LSOA includes only those individuals aged 70 and over, our analysis and results are constrained to such individuals. Overall, the LSOA includes information from reinterviews, the National Death Index (1984–1986) and medical links, and death certificates. Because the 1986 LSOA does not include all 1984 SOA participants aged 70 and over, new weights have been calculated for the 1986 LSOA reinterview sample. We have included these sample weights in all of our calculations to allow us to generalize our findings to the elderly population in the United States.

The LSOA is specifically designed to measure changes in the functional status, living arrangements, and mortality levels of older people in the United States. Indeed, it is ideally suited for our analysis, since it is designed to "describe the continuum from functionally independent living in the community through dependence, possible institutionalization, and finally death" (U.S. Department of Health and Human Services 1988, 1).

Construction of Active Life Measures

We classified respondents as dependent or independent on the basis of their ADL responses. Although other measures are available (see Cornoni-Huntley et al. 1985, 358–62), different measures yield different results, and because studies do not consistently employ the same measures, comparative findings must be evaluated with care. Previous studies have used the following four ADL variables to classify dependents: the ability to bathe, dress, transfer (get in or out of a bed or chair), and eat without assistance (see Katz et al. 1983; Rogers, Rogers, and Branch 1989).

Although we calculated active life expectancies using both four and seven ADLs, because the differences in life expectancy between these two schemes were quite small, for brevity, we present here life-table results based on seven ADLs. Such tables provide a more comprehensive measure of dependency and allow the separation of dependency into more and less dependent statuses. Even though the differences in life expectancies based on four versus seven ADLs are negligible, we must be cautious not to overstate the actual dependence of the elderly. The seven variables include the previous four ADLs plus one's ability to walk, toilet (get to or use the toilet), and get outside. Respondents were considered dependent if they received help from another person in carrying out these tasks.

We have constructed two schemes with these ADLs. First, if respondents were dependent in any one of these seven variables or were institutionalized (in 1986), they were defined to be in the dependent status. Second, we disaggregated dependents into the less dependent, where the respondents were dependent in one or two ADLs, and the more dependent, where the respondents were dependent in three to seven ADLs or were institutionalized. Because of the modest sample size, we have disaggregated the dependent population into two rather than three categories. We could have defined the less-dependent category as only one ADL, rather than rely, as we have, on one or two ADLs. Our decision to use one or two ADLs was based on the distribution of the ADL responses and a visual inspection and comparison of our initial calculations of transitions.

The more dependent category includes individuals with three or more ADLs and individuals who are institutionalized. Therefore, the results provide an accurate portrayal of the more-dependent population, as defined. Because this category includes the institutionalized population, a population which is presumably "too frail" to live in the community, transitions may understate the chances that noninstitutionalized individuals who have three ADLs will return to a less dependent or active status.

There is heterogeneity in rates of aging, within functional statuses, and in transitions among functional statuses (Manton 1988; Manton and Soldo 1985). For instance, individuals who become dependent may be more likely to return to independent status if they successfully manage chronic diseases that affect their disabilities and undergo surgery, therapy, or rehabilitation for any acute conditions. To deal with such heterogeneity, we have devised three, rather than two functional statuses. We believe that there are at least two groups of dependent individuals. The first group is comprised of those who, because of a temporary and usually acute rather than chronic problem, have become dependent. This is a transitory stage from which individuals are likely to recover and return to independence. (If their health status worsens, they move to a more-dependent category.) In contrast, the second group most likely exhibits chronic conditions that are not as well managed, shows untreated or untreatable acute conditions, displays slower rates of recovery, and contains individuals who are more likely to stay dependent or to become institutionalized.

Manton (1988) has shown that the chances are greater that a disabled individual will functionally improve or die rather than become institutionalized. Even though the institutionalized population is small, it is important from a health services standpoint. In the LSOA, the institutionalized population is too small to analyze separately. In addition, the institutionalized population cannot be considered as a separate status from which to establish transitions because the initial interviews in 1984 included only noninstitutionalized individuals. Only in the reinterview were individuals identified as residing in institutions. Although it is important to distinguish individuals with many functional limitations from those who are institutionalized, because of data limitations we have combined institutionalized individuals with the more-dependent respondents.

Starting with a sample of 5,151 respondents, we deleted 380 cases (7 percent) due to missing values, consistent nonresponses on ADL items, and losses to follow-up.

Calculation of Mortality Rates

To construct multistate life tables, we first estimated the probability of surviving between exact ages x and $x + n$ from the observed age-specific central death rates of these respondents aged 70 and over. Life tables do not have to be based on data at birth, but can be based at virtually any age and can estimate life expectancies for those ages and subsequent ages for which there are data. In this article, we construct life expectancies for ages 70 and over. Statistically, events before age 70 do not affect the average remaining life at that age or any later age (e.g., age 75).

Deaths were ascertained through informants during attempted reinterviews, follow-up interviews with the sample person's named contact or next-of-kin, and National Death Index matches. A total of 632 individuals died between the years 1984 and 1986. Because the survey covers multiple years, several statuses, some unknown years of death, and is relatively modest in size, we constructed mortality rates based on multiyear risks for *each status*, distributed deaths in unknown years proportionally to the known years in the study, and smoothed mortality rates by graduating them with an exponential function of mortality. Comparing our calculated aged-specific mortality rates for the total population with published values confirmed that our technique produced satisfactory results (for more detail, refer to Belanger 1988).

Multistate Life Tables

Methods of multistate life table analysis were originally developed to model the transitions experienced by individuals over time as they passed from one status to another: for example, from being single to being married, from being employed to being unemployed, from living in a rural region to living in an urban region.

The multistate model is based on the simplest time (age)-homogeneous Markov chain. To fit such a model to observed data, one normally posits constant intensities within each age interval or a piecewise linear specification of the life-table survival function (see Land and Rogers 1982).

A multistate analysis of active life expectancy can describe—in terms of life-table measures—the health of the elderly within a region, how many individuals move from one status to another, and, more importantly, how many return to previously occupied statuses. In this article, we build on previous active life findings (Rogers, Rogers, and Branch 1989) to model the transitions from independent to dependent functional statuses and vice versa.

Multistate Projections

The multistate model of demographic growth and change expresses the population projection process by means of a simple matrix operation in which a population set out as a vector is multiplied by a growth matrix that "survives" the population forward over time. The projection computes the status- and age-specific survivors and adds to this total the corresponding surviving new "births" or entrants. Specifically, to project the elderly population by functional status, we used the projection matrix developed by Rogers (1975). This matrix, denoted by G, is defined as:

$$G = \begin{bmatrix} 0 & 0 & B_{(a-5)} & \cdots & B_{(b-5)} & 0 & \cdots & 0 \\ S_{(0)} & 0 & 0 & & 0 & 0 & & 0 \\ 0 & S_{(5)} & 0 & & 0 & 0 & & 0 \\ 0 & 0 & \cdot & & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot & \cdot & S_{(z-5)} & 0 \end{bmatrix}$$

where the *Bs* are the fertility matrices associated with the population between ages *a* and *d*, the limits of childbearing, and the *Ss* are survivorship matrices. By defining *P* as a column vector containing the population distributed by functional status and age group, the population at time $t + 1$ is obtained through simple matrix multiplication:

$$P(t + 1) = GP(t).$$

We modified the matrix, however, because the elderly population does not reproduce itself. Our projections are based on the population already alive. Thus, the new entrants in each successive step of the projection cannot be a function of the previous year's population as in the multistate model. Accordingly, the *B* matrices were replaced by matrices of zeros and, for each projected year, the population for the first age group (i.e., 70 to 71) was extracted from the U.S. Bureau of the Census (1989) single year-of-age (and calendar time) population projections. (The U.S. Census Bureau reports population estimates by single years of age from 1988 through 2010; thereafter, it reports population estimates for every fifth year. Our estimates for the initial year, 1986, and for individual years, from 2011 through 2050, were obtained from Gregory Spencer of the Population Projections Branch, Population Division, U.S. Bureau of the Census, personal communication, March 8, 1989.) By projecting the population already alive, we avoid the problems associated with estimating fertility patterns. This eliminates a potentially large source of bias associated with projections (Guralnik, Yanagishita, and Schneider 1988; Olshansky 1988).

Because we excluded about 7 percent of the individuals from the LSOA, we must adjust our figures if we are to produce accurate population projections. We rescaled our initial 1986 population with the age distribution presented in the U.S. Census Bureau's series 14 projection, the middle series. This projection, the U.S. Census Bureau's (1989) "best estimate," assumes future declines in mortality and positive net migration. Our projection adds new 70 to 71-year-olds to the elderly population base and then ages them, and thus implicitly introduces the U.S. Census Bureau's assumptions. On the other hand, our multistate analyses assume a *closed* population—no international migration—and that current mortality schedules by functional status will continue into the future after age 70. Therefore, compared to the middle series of the census, our projected elderly population for future years will be somewhat smaller and our age structure will be slightly younger. The younger age structure may produce a slight overestimate of our projected proportion of independent elderly. Our final projections, in 2050, however, are quite similar to the U.S. Census Bureau's (1989) series 19 projections, projections that assume slight declines in mortality and low net immigration. Moreover, through such adjustments, we can project the same levels of population by age as did the U.S. Census Bureau, include our multistate transitions by active status, and retain the LSOA information on individuals at the older ages.

Accurately projecting active life among the elderly is a difficult task. For instance, there is uncertainty about how the age and sex distributions of activity might change. Mortality has declined over time, but it is unclear whether morbidity declined too (Guralnik, Yanagishita, and Schneider 1988, 304). Lacking the necessary data, we distributed each first new age group (70 to 71 years) across the different functional statuses according to the distribution observed for the same age group in the 1986 LSOA panel. We then projected the functional status of the elderly to the year 2050 using a program written in *GAUSS* (1988), a mathematical computer language. The S matrices were formed from the S_{ij} already calculated and printed as an intermediary output from the program set forth in Willekens and Rogers (1978) which was used for the life-table analysis.

Findings

Our findings are reported in four parts. First, we examine active life expectancies in terms of two functional statuses for the total United States population. Second, we disaggregate these expectancies by sex. Third, we explore the use of three rather than two statuses. Finally, we project the future active population both for the two-status and the three-status models; the former also includes disaggregation by sex.

National Active Life Expectancies

Table 2 records the active life expectancies for the total United States population, according to initial independent and dependent functional statuses. We calculated active life expectancies for whites; however, the years lived and percentage time spent in each status were essentially identical in those of the entire population. Because whites are the

TABLE 2
Expectations of Remaining Life for Individuals Aged 70 and Over: Two Functional Statuses, United States, 1984*

	A. Independent at age *x*			B. Dependent at age *x*		
Age *x*	Total remaining years	Remaining independent years	Remaining dependent years	Total remaining years	Remaining independent years	Remaining dependent years
70	13.4	10.1 (75%)	3.4 (25%)	12.5	6.4 (51%)	6.1 (49%)
72	12.2	8.9 (73)	3.3 (27)	11.3	5.5 (48)	5.8 (52)
74	11.1	7.8 (71)	3.3 (29)	10.1	4.1 (41)	6.0 (59)
76	10.0	6.8 (68)	3.2 (32)	8.9	2.8 (32)	6.1 (68)
78	9.0	5.9 (66)	3.1 (34)	8.0	2.4 (29)	5.7 (71)
80	8.1	5.2 (63)	3.0 (37)	7.2	2.0 (28)	5.2 (72)
82	7.3	4.5 (61)	2.8 (39)	6.5	1.6 (25)	4.9 (75)
84	6.6	3.9 (59)	2.7 (41)	5.9	1.4 (24)	4.5 (76)
86	6.0	3.4 (57)	2.6 (43)	5.3	1.1 (21)	4.2 (79)
88	5.5	3.1 (56)	2.4 (44)	4.8	0.9 (18)	4.0 (82)
90	5.2	2.9 (56)	2.3 (44)	4.5	0.8 (19)	3.7 (81)
92	4.9	2.6 (53)	2.3 (47)	4.3	0.8 (19)	3.5 (81)

Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988).
* Based on 7 ADLs. Percentages may vary due to rounding.

largest proportion of the total population, such findings seem reasonable. Unfortunately, the black population in the data set, even though oversampled, is still too small to examine and compare separately. Therefore, we have reported the results for the total population only. We report age in even-numbered years, beginning at age 70, because the LSOA began at age 70 and reinterviewed respondents two years later. Therefore, the risk of an occurrence of an event is calculated over a two-year interval. We focus on ages 70 to 90. In closing any life table, the terminal open-ended age group sometimes gives values that are unrepresentative when compared to those of previous ages. Therefore, we calculate and report life expectancies for age 92, but direct our efforts to examining younger life expectancies. Overall, life expectancies decrease with increasing age, and the proportion of time spent in an independent status decreases correspondingly. Further, life expectancies are higher for the independent than the dependent population.

Panel A records that individuals who were *independent* at age 70 can expect to live another 13.4 years, on average, of which total 75 percent can be expected to be spent in the active status and 25 percent in the dependent status. (A previous multistate analysis of data for Massachusetts showed that 87 percent of a baseline independent person's remaining lifetime would continue to be active [Rogers, Rogers, and Branch 1989].) Individuals who were independent at age 90 can expect to live another 5.2 years, of which 56 percent can be expected to be spent in the active status and 44 percent in the dependent status.

Panel B records that individuals who were *dependent* at age 70 can expect to live another 12.5 years, on average. Such individuals can expect to live about one-half of their remaining years in active life (i.e., by a "recovery"). (Multistate estimates for the Massachusetts study indicated that such individuals could expect to spend about 68 percent of their remaining years in an active status [Rogers, Rogers, and Branch 1989].) Individuals in the United States who were dependent at age 90 can expect to live another 4.5 years, of which 80 percent will be spent in the dependent status. With increasing age, the chances of experiencing life in a dependent status increases and the chances of experiencing a recovery decreases.

Figure 2 displays graphically the functional status of the elderly population in the United States. Although other researchers have set forth survival curves for the total population or for hypothetical active subpopulations (see, for example, Manton and Soldo 1985), such survival trends do not provide much additional insight in *multistate* analyses of elderly active life. First, because we are examining the elderly, those individuals aged 70 and over, we begin with life-table radices of 100,000 at age 70 and not at age 0. Thus, the proportion of people surviving to the next age does not parallel the relation found in a life table that begins at birth. Second, because multistate techniques allow individuals to transfer from any given status to another, and begin with multiradices, survival rates give information not only on how much time is spent in a particular status (survival), but also how much time is spent in one status before moving on to another status (transition). For these reasons, our graphic representations of active life with transitions are based on expectations of life rather than on survival probabilities.

Figure 2 illustrates active life expectancies for individuals who were initially independent (panel A) and initially dependent (panel B). The uppermost curve in each panel shows the total life expectancy. Thus, panel A records that individuals who were independent at age 70 could

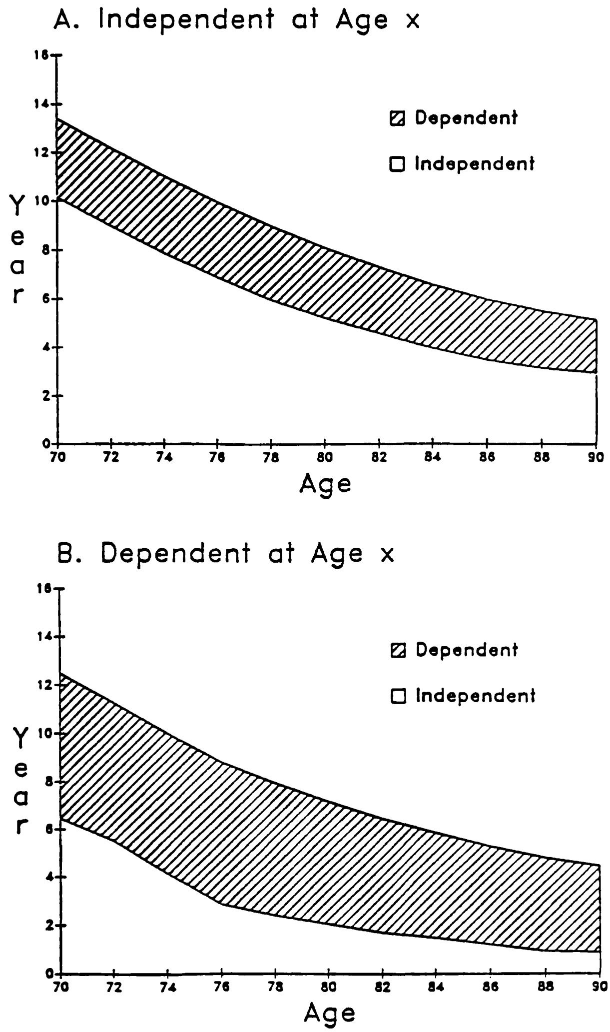


FIG. 2. Expectations of remaining life for individuals aged 70 and over: Two functional statuses, United States, 1984.
Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988).

expect to live an additional 13.4 years, on average. The area between the horizontal axis and the first line denotes years of active life. Thus, in panel A, an individual who is independent at age 70 can expect to live an additional 10.1 years in an active status. The area between the uppermost line and the bottom line indicates the amount of time expected to be spent in the dependent status. Thus, again in panel A, an individual who is independent at age 70 can expect to spend 3.3 years in the dependent status (13.4 years minus 10.1 years). Overall, individuals who are independent at age x relative to those who are dependent at age x can expect longer, more active lives, with a smaller proportion of time spent in a dependent status (compare panels A and B).

Active Life Expectancies by Sex

Besides age, sex is one of the variables most strongly associated with life expectancy and one that is frequently reported in the literature. Therefore, we present in table 3 expectations of active life disaggregated by sex as well as by age.

At every age and for baseline independent and dependent populations, females are expected to live longer than males. For instance, for those who are independent at age 70, females can expect to live an additional 15.4 years, whereas males can expect just 11.3 more years of life. Much of the excess life expectancy of females relative to males is likely to be spent in the dependent status. This is particularly true for those who are initially dependent. For example, females who are independent at age 70 can expect to live 4.1 years longer than their male counterparts. Of these 4.1 excess years, 2.5 will be spent as dependent. Thus, over 60 percent of the excess remaining years are expected to be spent in a dependent status. Similarly, even though initially dependent, females can expect to live longer than males, with the excess comprised of years in the dependent status. Females who are dependent at age 70 can expect to live 4.6 years longer than their male counterparts, but 3.7 of these "extra years" will be in a dependent status. Here, 80 percent of the excess years are spent in a dependent status. Since dependency increases with age, increasing life expectancy increases the chances and proportions of time spent in a dependent status.

Thus, although females live longer, many of their additional years of life are in the dependent status. Such findings are in accord with the literature on male/female differences in morbidity and mortality (Bebbington 1988; Manton 1988; Manton and Soldo 1985), and underscore the need not only to increase the survival of both sexes but also to improve the quality of life and the level of transitions from dependency to active life among the elderly.

As figure 3 illustrates, males can expect to live shorter lives than females, but lives with proportionately less dependence.

TABLE 3
Sex-specific Expectations of Remaining Life for Individuals Aged 70 and Over: Two Functional Statuses, United States, 1984*

	A. Independent at age *x*			B. Dependent at age *x*		
Age *x*	Total remaining years	Remaining independent years	Remaining dependent years	Total remaining years	Remaining independent years	Remaining dependent years
			I. Males			
70	11.3	9.3 (82%)	2.0 (18%)	9.9	5.9 (60%)	4.0 (40%)
72	10.2	8.2 (80)	2.2 (20)	9.1	5.3 (58)	3.8 (42)
74	9.2	7.2 (78)	2.0 (22)	8.1	4.3 (53)	3.8 (47)
76	8.3	6.3 (76)	2.0 (24)	7.2	3.1 (44)	4.0 (56)
78	7.4	5.5 (73)	2.0 (27)	6.5	2.6 (40)	3.9 (60)
80	6.7	4.8 (71)	1.9 (29)	5.9	2.0 (35)	3.8 (65)
82	6.0	4.2 (69)	1.9 (31)	5.4	1.7 (31)	3.7 (69)
84	5.5	3.6 (66)	1.9 (34)	5.0	1.5 (30)	3.5 (70)
86	5.0	3.1 (62)	1.9 (38)	4.5	1.1 (24)	3.4 (76)
88	4.5	2.7 (59)	1.9 (41)	4.2	0.8 (20)	3.4 (80)
90	4.2	2.2 (53)	2.0 (47)	4.0	0.6 (16)	3.4 (84)
92	3.9	1.5 (38)	2.4 (62)	3.8	0.6 (14)	3.3 (86)
			II. Females			
70	15.4	10.9 (71%)	4.5 (29%)	14.5	6.8 (47%)	7.7 (53%)
72	14.0	9.6 (68)	4.4 (32)	13.0	5.6 (43)	7.4 (57)
74	12.6	8.4 (66)	4.2 (34)	11.6	4.0 (35)	7.5 (65)
76	11.4	7.4 (64)	4.1 (36)	10.3	2.8 (28)	7.4 (72)
78	10.3	6.3 (62)	3.9 (38)	9.3	2.5 (27)	6.7 (73)
80	9.2	5.5 (59)	3.7 (41)	8.3	2.2 (26)	6.1 (74)
82	8.3	4.8 (58)	3.5 (42)	7.5	1.8 (25)	5.6 (75)
84	7.5	4.2 (56)	3.3 (44)	6.7	1.6 (24)	5.1 (76)
86	6.8	3.7 (54)	3.1 (46)	6.1	1.4 (23)	4.7 (77)
88	6.2	3.4 (55)	2.8 (45)	5.5	1.1 (20)	4.4 (80)
90	5.9	3.4 (58)	2.5 (42)	5.1	1.1 (21)	4.0 (79)
92	5.7	3.4 (61)	2.2 (39)	4.9	1.1 (22)	3.8 (78)

Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988).
*Based on 7 ADLs. Percentages may vary due to rounding.

Extension: Three Functional Statuses

Multistate life-table methods assume homogeneity of the population regarding the risk of making a transition from one given status to another. To increase homogeneity among population groups, users of multistate techniques usually increase the number of categories, for example, by analyzing each sex separately. It is, of course, impossible to control completely for heterogeneity. In the present case, however, the dependent status appears as a highly heterogeneous group; it includes people with only one ADL as well as people who are institutionalized. Such diverse groups may exhibit different transitions and mortality rates. To quantify the impact of this possible source of heterogeneity, we have extended our analyses to include three functional statuses. In addition to the independent status, which remains the same as in the above analysis, the dependent category has been subdivided into two groups, "less" and "more" dependent. If heterogeneity is not a major factor, the results of the two and three functional-status analyses should

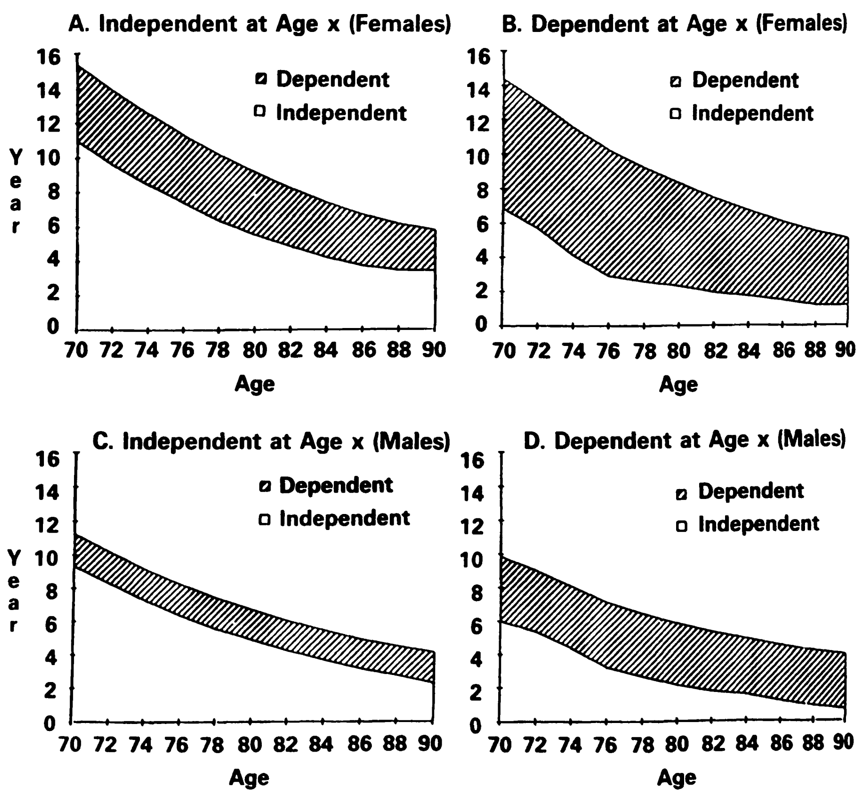


FIG. 3. Sex-specific expectations of remaining life for individuals aged 70 and over: Two functional statuses, United States, 1984.
Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988).

be quite similar. On the other hand, if heterogeneity is an important factor in elderly health, then we should obtain quite different results.

We conceptualize the less-dependent status, then, as transitional rather than permanent—individuals most likely pass from independence to less and then more dependence, or individuals move from independence to less dependence and then back to independence. The more dependent status, we hypothesize, is apt to be permanent, with fewer individuals moving out of this status.

Table 4 records the active life expectancies associated with the following three functional statuses: independent, less dependent, and more dependent. Such statuses provide more information on the actual dependencies of the elderly than the two-status analysis shown in table 2. Note that the total remaining years of life expected are greater at each age for those who were baseline independent rather than less dependent, and that they are greater at each age for those who are less rather than more dependent. Generally, active life expectancies decrease with increasing age. Nevertheless, even at the older ages, there are strong possibilities to remain or become independent.

Panel A of table 4 displays life expectancies for the baseline independent status (see also, figure 4A). The data for the baseline independent population in tables 2 and 4 are quite similar. Dissimilarities are due to differential transitions between the independent and the different dependent subpopulations. Increasing age increases time expected to be spent in a dependent status. For example, individuals who are independent at age 70 can expect to spend 10 percent of their remaining time in a less-dependent status and 15 percent in a more-dependent status; individuals who are independent at age 90 can expect to spend 16 percent of their time in a less-dependent status and 30 percent in a more-dependent status. Therefore, individuals not only spend more time in a dependent status with age, but they also spend more time in a *more* dependent status. Nevertheless, individuals who are independent at one age can usually retain their independence.

Panel B of table 4 displays life expectancies for the baseline less-dependent status (see also figure 4B). Generally, less dependent individuals can expect to spend the majority of their remaining lifetime in a dependent status. For example, less dependent individuals at age 70 can expect to live another 11.9 years, of which only one-half can be expected to be lived in the active status. Individuals who were less dependent at age 90 can expect to live another 4.9 years, of which 16 percent can be expected to be lived in the active status. Less-dependent individuals at most ages can expect to live between one-quarter and one-third of their remaining lifetime in a less-dependent status. Moreover, these individuals at older ages can expect to spend between one-quarter and one-half of their expected lifetime in a more-dependent status.

TABLE 4
Expectations of Remaining Life for Individuals Aged 70 and Over: Three Functional Statuses, United States, 1984*

Age *x*	Total remaining years	Remaining independent years	Remaining less-dependent years	Remaining more-dependent years
		A. Independent at age *x*		
70	13.2	9.9 (75%)	1.3 (10%)	2.0 (15%)
72	12.0	8.7 (72)	1.3 (11)	2.0 (17)
74	10.9	7.7 (70)	1.3 (12)	2.0 (18)
76	9.9	6.7 (68)	1.2 (12)	2.0 (20)
78	9.0	5.8 (65)	1.2 (13)	2.0 (22)
80	8.1	5.1 (62)	1.2 (14)	1.9 (24)
82	7.4	4.4 (60)	1.1 (14)	1.9 (26)
84	6.7	3.8 (57)	0.9 (14)	1.9 (29)
86	6.1	3.4 (55)	0.9 (14)	1.9 (31)
88	5.7	3.1 (54)	0.8 (15)	1.8 (31)
90	5.4	2.9 (54)	0.8 (16)	1.6 (30)
92	5.1	2.7 (53)	1.0 (20)	1.4 (27)
		B. Less dependent at age *x*		
70	11.9	6.2 (52%)	2.9 (24%)	2.8 (24%)
72	10.9	5.4 (49)	2.8 (26)	2.7 (25)
74	9.8	4.3 (44)	2.9 (30)	2.6 (26)
76	8.7	3.0 (34)	3.0 (34)	2.7 (32)
78	7.9	2.4 (31)	2.8 (35)	2.7 (34)
80	7.3	2.1 (29)	2.7 (37)	2.5 (34)
82	6.7	1.7 (25)	2.6 (39)	2.4 (36)
84	6.1	1.5 (25)	2.2 (37)	2.4 (38)
86	5.6	1.3 (23)	2.1 (37)	2.3 (40)
88	5.2	0.9 (17)	1.9 (37)	2.4 (46)
90	4.9	0.8 (16)	1.9 (39)	2.2 (45)
92	4.9	0.6 (12)	1.5 (30)	2.9 (58)

continued

TABLE 4 (Continued)

Age *x*	Total remaining years	Remaining independent years	Remaining less-dependent years	Remaining more-dependent years
C. More dependent at age *x*				
70	10.8	3.8 (35%)	1.5 (14%)	5.5 (51%)
72	10.0	3.6 (36)	1.3 (13)	5.1 (51)
74	9.0	2.7 (31)	1.5 (16)	4.8 (53)
76	8.0	1.9 (24)	1.4 (18)	4.7 (58)
78	7.4	1.6 (22)	1.3 (17)	4.5 (61)
80	6.7	1.3 (20)	1.2 (18)	4.1 (62)
82	6.1	1.1 (19)	1.0 (16)	3.9 (65)
84	5.5	0.9 (17)	0.8 (14)	3.8 (69)
86	5.0	0.7 (14)	0.6 (12)	3.7 (74)
88	4.6	0.5 (12)	0.4 (9)	3.6 (79)
90	4.3	0.6 (13)	0.4 (9)	3.4 (78)
92	4.1	0.6 (14)	0.4 (9)	3.2 (77)

Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988).
* Based on 7 ADLs (less dependent is defined in 1 or 2 ADLs; more dependent is defined as dependent in 3 to 7 ADLs or institutionalized. Percentages may vary due to rounding.

Nevertheless, those individuals who are less dependent still have a chance of regaining their independence, even at quite old ages.

Panel C of table 4 displays life expectancies for the more dependent baseline population (see also figure 4C). More-dependent individuals can expect to spend the majority of their remaining lifetimes in the more-dependent status. More-dependent individuals at age 70 can expect to live 10.8 additional years, of which one-third will be spent in an active status. More-dependent individuals at age 90 can expect to live 4.3 added years, of which about 13 percent will be spent in an active status; three-quarters of the remaining lifetime will be spent in a more-dependent status. Most individuals who become more dependent remain more dependent.

Figure 4 illustrates the expectations of remaining life for each status. The baseline independent population can look forward to a lengthy active life (panel A). Baseline individuals who are less dependent will have to balance active lives with years of dependency, periods with

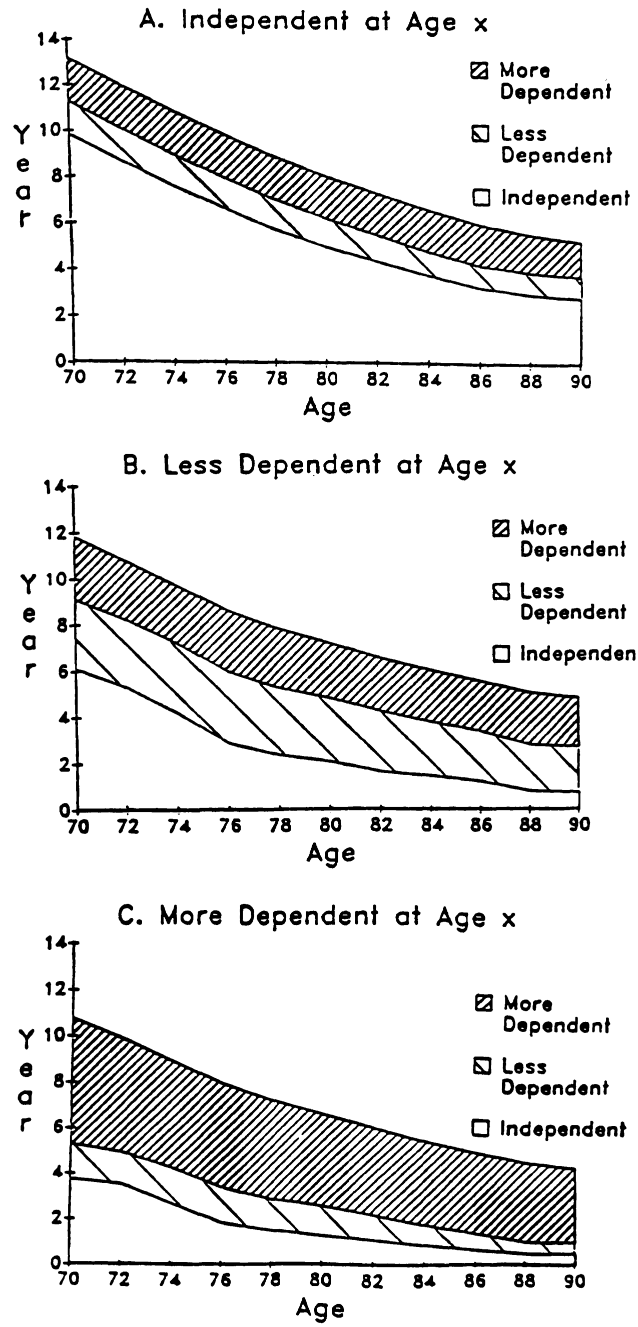


FIG. 4. Expectations of remaining life for individuals aged 70 and over: Three functional statuses, United States, 1984.
Source: Calculations based on LSOA data (U.S. Deptartment of Health and Human Services 1988).

both minor and more major limitations of activity (panel B). Baseline individuals who are more dependent will generally remain dependent, but with a chance of returning to an active status. Such relations, with three functional statuses, illustrate the heterogeneity of the dependent elderly populations, and more accurately describe their functional statuses and expected transitions.

Projections: Two Functional Statuses by Sex

Life-table estimates are important insofar as they accurately describe the current life chances of a group, say, the elderly. Life-table-based projections are significant in that they can provide us with alternative scenarios that can guide health planners and policy makers in their efforts to anticipate future elderly health, economic, and social needs.

Projected elderly population totals, disaggregated by functional statuses and sex, are shown in figure 5. Note that, although male and female populations disaggregated by functional status exhibit similar patterns, because of the greater female longevity, there are substantially more females than males. The patterns indicate increases in the number of dependent and independent individuals from the present until the 2040s. Indeed, the dependent female population will steadily increase from 2.8 million in 1986 to a high of 8.6 million in the year 2044 (see table 5, which includes selected years, for brevity). The projected growth rates (not shown) emphasize the increases in the dependent population. For example, the growth rates indicate an increasing dependent female population from 1986 through 2044, with a high growth rate in the year 2028, around the time when many individuals from the Baby Boom cohort will have entered the elderly population.

The independent female population displays a similar pattern, but with more people. For example, this independent population will increase from 9.5 million women in 1986, dip slightly for a few years at the turn of the century, and then rise to a peak of 19 million women in 2036. Again, the growth rates help us understand these trends. The growth rates indicate an independent population that increases from 1986 through 2002, decreases from 2004 to 2006, but then increases from 2008 through 2036, with a peak in 2020. Because of the momentum for population aging, even though the growth rate peaks in 2020,

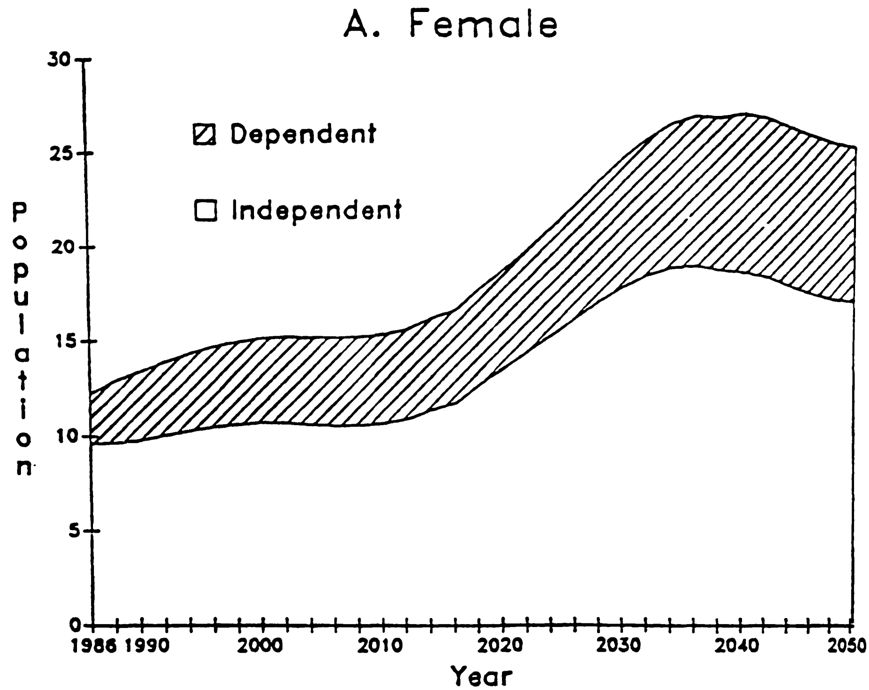


FIG. 5. Sex-specific projected population aged 70 and over: Two functional statuses, United States, 1986–2050 (population in millions).
Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988). (*Figure continued on facing page.*)

the independent population will continue to increase in size until about 2036. From 2038 through 2050, the growth rates indicate a declining independent population. The pattern for males is similar. Overall, the independent male and female populations will each double in 50 years, but the *dependent* male and female populations will triple in less than 60 years. Therefore, even though the independent population is larger over the next 50 years, the dependent population will increase faster and will peak at a later period.

The data exhibit similar ebbs and flows in the percentages of elderly males and females who are dependent (see figure 6). For example, the percentage of dependent females increases from a low of 23 percent in 1986 to 32 percent in 2008. It then declines to 28 percent in the year 2026, increases to a peak in the year 2048, and ends in 2050 with a slight decline (see panel B for a similar pattern among males). This ebb and flow is generated by the changing age structure of the elderly pop-

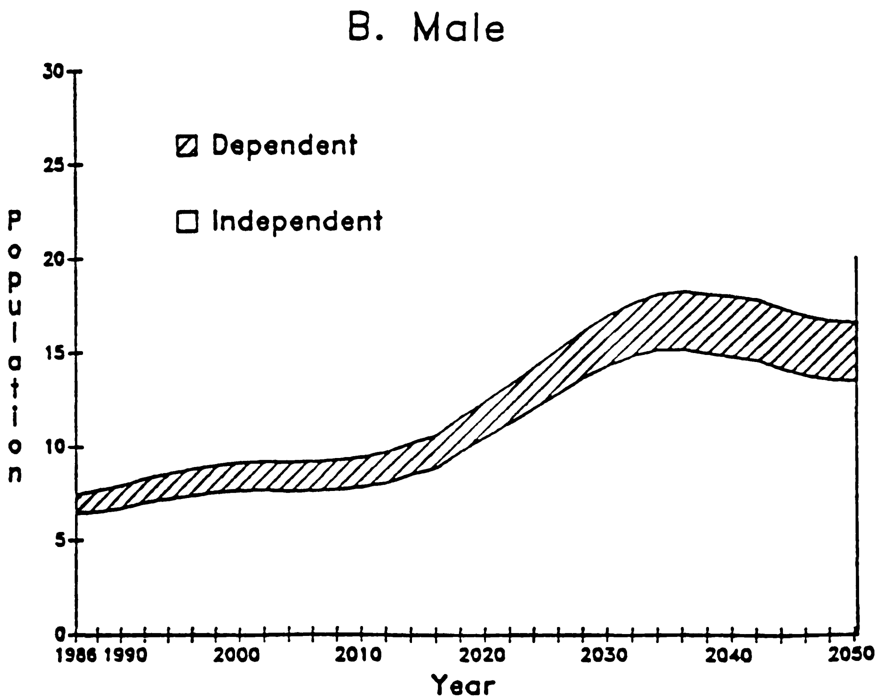


FIG. 5 (Continued.)

ulation. Indeed, the percentage of the elderly population that is older (age 86 and above) coincides with the percentage of the elderly population that is dependent (see figure 6).

Population pyramids for the years 1990, 2010, 2030, and 2050 (figure 7) graphically illustrate the interactions among age, sex, dependency, and time. Several features of these pyramids are noteworthy. Clearly, females outnumber males at every age. Further, as we saw in figure 5, the elderly population increases in size from 1990 through 2030, and then declines in size as various cohorts enter, age through, and exit the population; the age structure undergoes constant and dramatic change. Between the years 1990 and 2010, the age structure becomes relatively evenly distributed. By 2030, however, the elderly population pyramid resembles the traditional population pyramids of the general populations in less-developed countries (LDCs). Note its wide base, its steep decline in population size with each successive age group, and its narrow top. When LDC pyramids display a large base because of high fertility, the United States elderly pyramid base in 2030 is large due to high fertility 70 years earlier. As the Baby Bust ba-

TABLE 5
Sex-specific Projected Population Aged 70 and Over: Two Functional Statuses, United States, 1986–2050 (in thousands)

Age	1986	1990	2000	2010	2020	2030	2040	2050
				Independent				
				A. Males				
70	1,313	1,428	1,521	1,624	2,514	3,128	2,740	2,696
72	1,148	1,233	1,362	1,376	2,274	2,771	2,380	2,279
74	1,012	1,025	1,189	1,163	1,511	2,318	2,219	1,930
76	798	851	1,001	939	1,326	1,863	2,012	1,623
78	644	669	812	777	931	1,404	1,659	1,432
80	481	490	580	618	660	1,021	1,271	1,113
82	374	355	416	459	464	767	934	802
84	224	244	278	322	315	410	628	601
86	182	163	185	218	204	288	405	438
88	90	93	112	137	131	157	237	280
90	71	57	63	75	80	86	132	165
92+	28	40	47	56	62	63	103	126
Total	6,365	6,648	7,566	7,764	10,472	14,276	14,720	13,485
				B. Females				
70	1,673	1,728	1,774	1,846	2,779	3,360	2,937	2,881
72	1,598	1,586	1,700	1,652	2,656	3,132	2,690	2,556
74	1,411	1,420	1,563	1,457	1,854	2,735	2,601	2,248
76	1,208	1,253	1,376	1,236	1,698	2,311	2,453	1,975
78	989	1,027	1,162	1,087	1,260	1,841	2,128	1,832
80	775	797	875	898	935	1,407	1,702	1,487
82	603	594	669	717	696	1,120	1,320	1,134
84	449	430	493	543	506	644	950	904
86	294	301	354	394	354	486	661	702
88	210	188	227	261	244	283	414	478
90	102	108	134	151	155	162	243	294
92+	207	241	299	348	373	363	583	688
Total	9,519	9,673	10,626	10,590	13,510	17,844	18,682	17,179

continued

bies age into their early and late 70s, in 2035 and later, we see a decline in the size of these age groups. Finally, the proportion of the population that is dependent increases with age. Therefore, as the elderly population ages, the proportion that is dependent increases. In

TABLE 5 (Continued)

Age	1986	1990	2000	2010	2020	2030	2040	2050
				Dependent				
				A. Males				
70	101	108	114	122	189	235	206	203
72	119	132	145	147	243	296	254	243
74	89	129	149	146	190	291	278	242
76	125	140	165	154	218	306	331	267
78	115	152	191	183	219	331	391	338
80	124	154	184	196	209	323	402	353
82	85	141	172	190	193	318	388	333
84	110	121	144	167	173	212	325	311
86	53	93	115	136	127	180	253	273
88	67	74	90	110	106	126	191	225
90	31	51	63	75	80	85	132	164
92+	113	115	137	163	180	182	301	366
Total	1,132	1,410	1,669	1,789	2,117	2,885	3,452	3,318
				B. Females				
70	198	214	219	228	343	415	363	356
72	167	245	262	255	410	483	415	395
74	211	279	310	289	368	543	516	446
76	234	312	373	335	460	626	664	535
78	274	366	449	420	486	711	822	707
80	311	393	478	491	511	769	929	812
82	297	398	492	527	512	824	972	834
84	259	374	466	515	480	610	900	856
86	246	322	416	465	417	574	781	829
88	191	265	354	409	383	443	648	749
90	183	205	274	311	320	332	501	605
92+	233	407	538	628	673	654	1,051	1,239
Total	2,804	3,780	4,631	4,873	5,363	6,984	8,562	8,363

Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988).

comparing the populations in 2030 and 2050, we see that the population size decreases, but the average age increases, and the proportion of the population that is dependent increases. Quite clearly, as the female population aged 92 and over increases, we see that a large number of

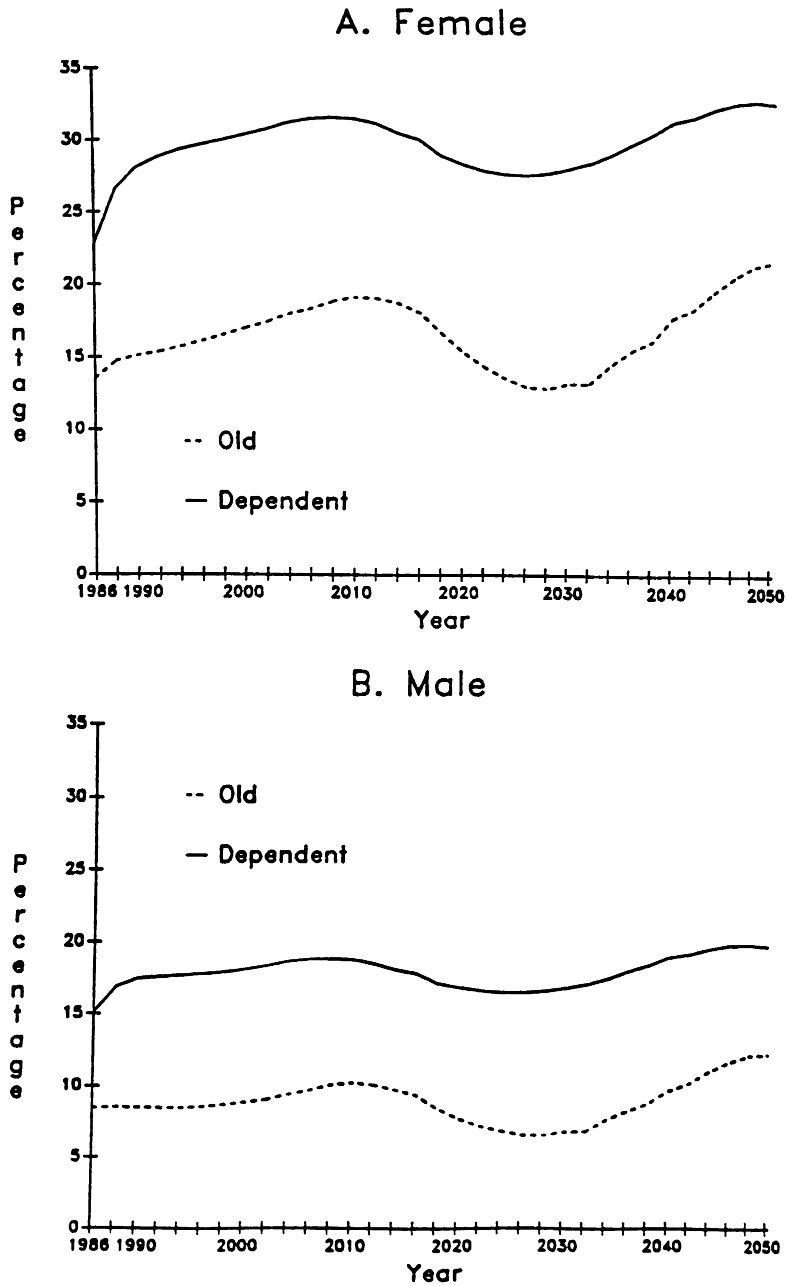
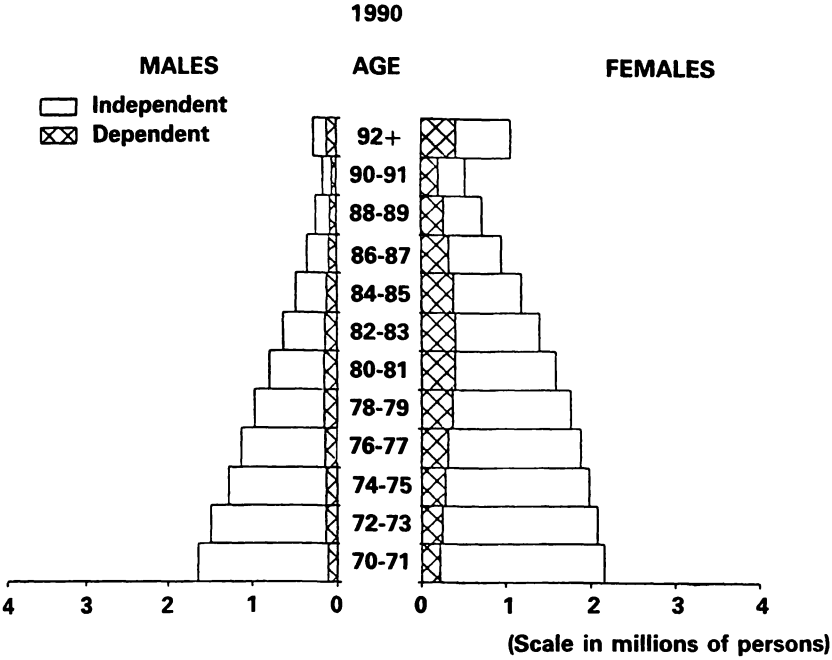


FIG. 6. Sex-specific projected proportions of the population aged 70 and over that is dependent, and that is older (aged 86 and over): United States, 1986–2050.
Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988).



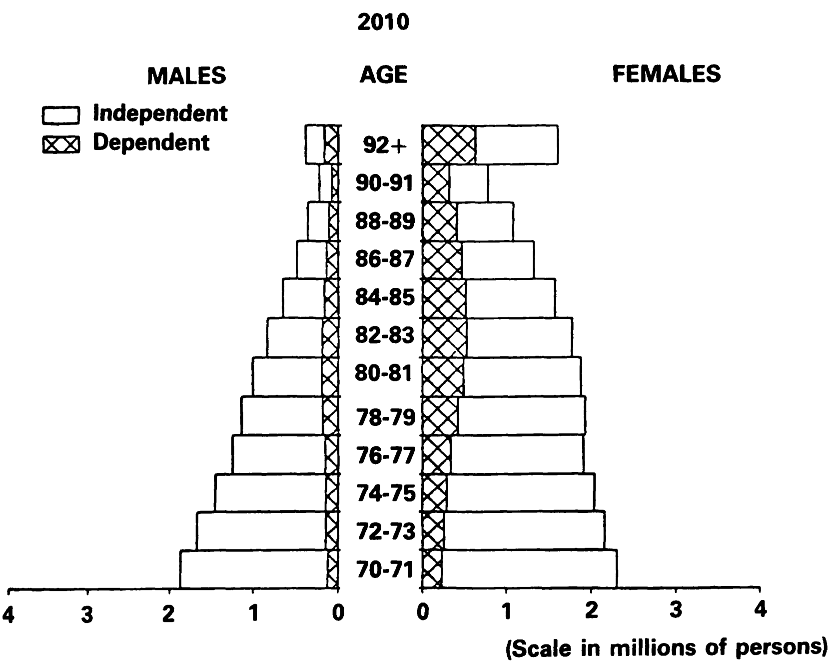


FIG. 7. Population pyramids for individuals aged 70 and over by functional status: Selected years, United States.
Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988). (*Figure continued on overleaf.*)

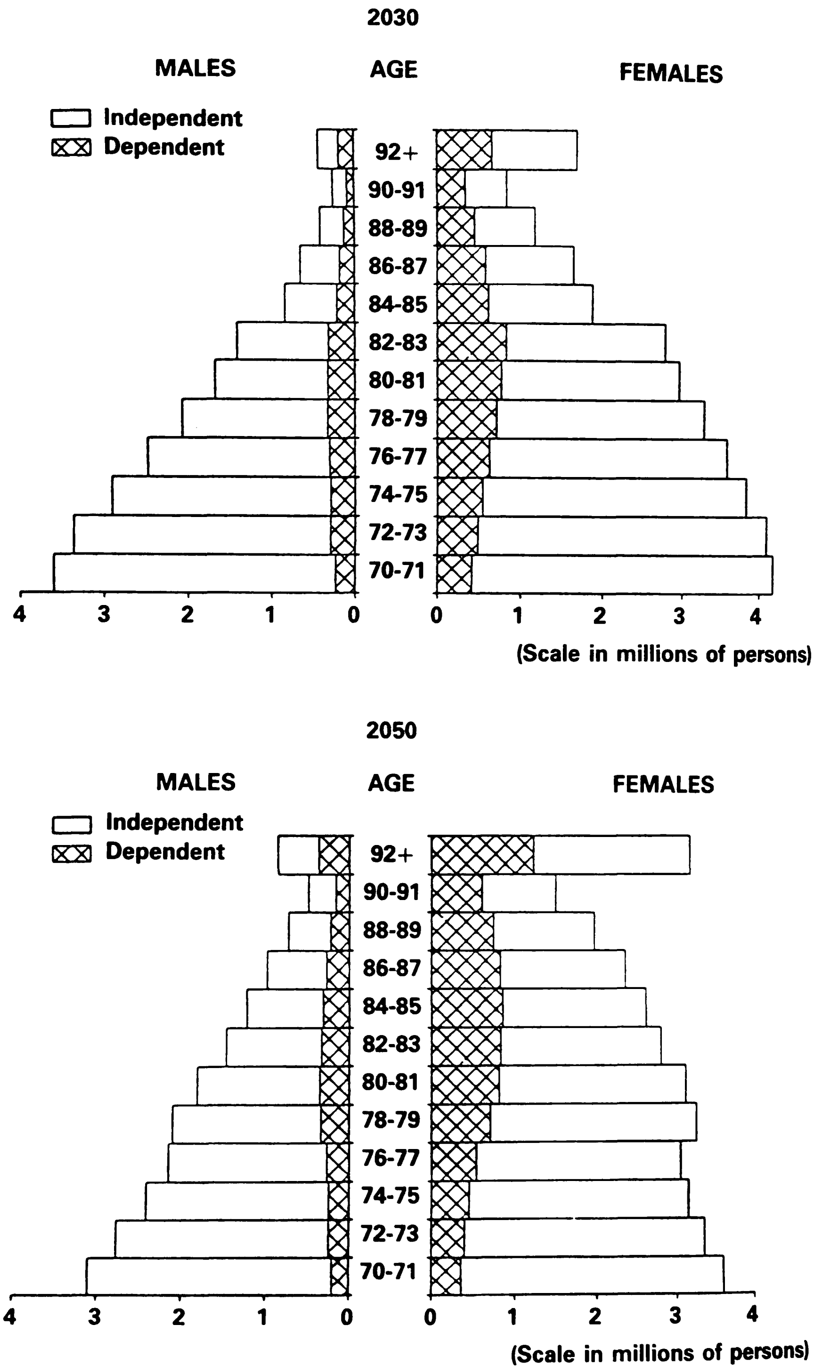


FIG. 7 (Continued.)

such elderly females will also be dependent. These pyramids, then, provide a vivid picture of the elderly population, with swings in the distributions of age and dependency over time.

Projections: Three Functional Statuses

The projected elderly population disaggregated by *three* functional statuses is shown in figure 8 (data size limitations have precluded calculating projections of three functional statuses by sex). At any one time, most elderly are likely to enjoy an active life. The status-specific trends, however, reveal interesting patterns. For instance, the pattern displayed by the projections is one of an increasing number of independent elderly until the year 2002 (see table 6 which includes selected years, for brevity). Then the independent population declines somewhat, but by 2008 the independent population increases once again. The growth

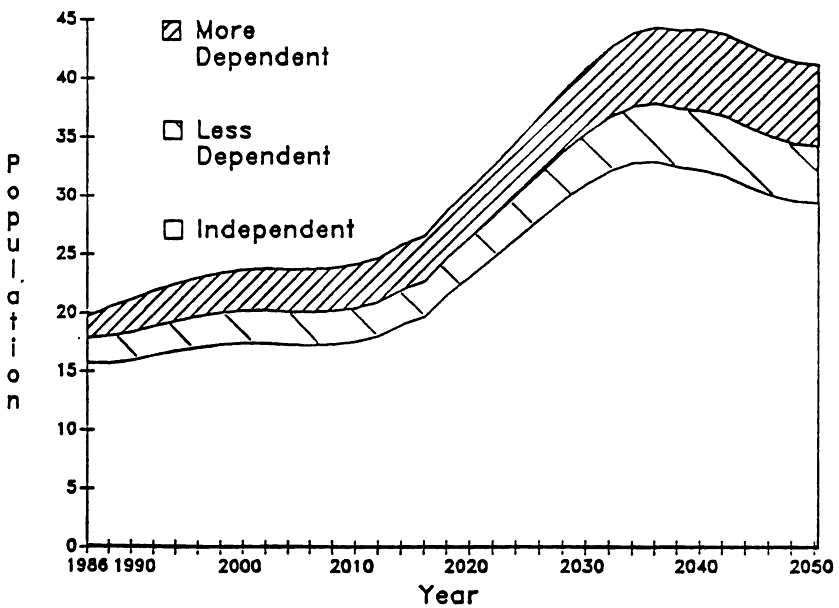


FIG. 8. Projected population aged 70 and over: Three functional statuses, United States, 1990–2050 (population in millions).
Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988).

rates underscore these trends and indicate that the independent population will grow most rapidly around the year 2018. Because of the momentum for population aging, however, the independent population should show steady increases until it peaks in size in 2036, at 33.2 million. After 2036, the independent population steadily declines in size.

TABLE 6
Projected Population Aged 70 and Over: Three Functional Statuses, United States, 1986–2050 (in thousands)

Age	1986	1990	2000	2010	2020	2030	2040	2050
				A. Independent				
70	2,983	3,158	3,294	3,469	5,289	6,481	5,671	5,571
72	2,746	2,799	3,039	3,006	4,895	5,861	5,034	4,800
74	2,423	2,402	2,708	2,579	3,313	4,967	4,748	4,115
76	2,006	2,075	2,328	2,133	2,976	4,098	4,385	3,534
78	1,634	1,684	1,926	1,820	2,141	3,175	3,708	3,196
80	1,250	1,264	1,401	1,461	1,539	2,346	2,875	2,516
82	974	926	1,029	1,117	1,105	1,799	2,154	1,850
84	672	658	720	812	773	933	1,492	1,424
86	475	454	497	562	515	716	989	1,058
88	299	271	306	355	335	395	585	683
90	169	155	171	193	201	212	323	396
92+	222	224	249	283	308	304	496	593
Total	15,853	16,070	17,668	17,790	23,381	31,356	32,460	29,736
				B. Less dependent				
70	172	183	190	201	306	375	328	322
72	137	175	191	188	307	367	316	301
74	165	187	210	200	258	387	369	320
76	193	211	245	225	313	432	462	372
78	157	224	272	257	302	448	524	451
80	218	243	283	295	311	474	581	509
82	204	252	298	324	321	522	625	537
84	211	221	257	289	276	354	532	507
86	116	165	197	223	205	285	393	421
88	118	113	137	159	150	177	262	306
90	61	72	86	97	101	107	163	199
92+	128	133	152	173	188	186	321	363
Total	1,880	2,179	2,518	2,631	3,038	4,114	4,876	4,608

continued

TABLE 6 (Continued)

Age	1986	1990	2000	2010	2020	2030	2040	2050
				C. More dependent				
70	130	137	143	151	230	282	247	242
72	149	209	226	224	365	437	375	358
74	135	236	266	253	325	489	466	404
76	166	245	299	274	381	527	564	454
78	231	283	365	345	406	601	702	605
80	223	305	375	391	412	628	769	673
82	181	299	358	389	384	626	749	644
84	159	275	337	379	361	464	697	665
86	185	252	321	365	334	464	641	686
88	141	231	298	348	329	387	574	670
90	156	188	244	277	289	304	463	568
92+	281	405	501	573	622	616	1,002	1,200
Total	2,137	3,065	3,733	3,969	4,438	5,825	7,249	7,169

Source: Calculations based on LSOA data (U.S. Department of Health and Human Services 1988).

Unlike the independent population, the less-dependent population steadily increases from 1986 until the year 2042. It then slowly declines. The more-dependent population also shows a steady increase and peaks in the year 2044, with 7.3 million people. Such trends illustrate how the elderly population will increase throughout the first half of the next century. This information highlights the need for elderly service agencies to be aware of the increased dependency levels expected around the year 2050. Furthermore, these numbers indicate that, even when the independent population will begin to decline, the more-dependent elderly—those requiring more health services—will still be increasing in size.

Figure 9 illustrates, once again, that age and dependency are interrelated. Clearly, as the population ages, the proportion of the elderly population that is dependent should increase. Between the years 1986 and 2050, the independent population is projected to increase less than two-fold, but the less-dependent population will increase more than two-fold, and the more dependent population will increase over three-fold. Indeed, the more dependent population will increase from 2.1 to 7.2

million individuals. Such data, then, disaggregated by functional status and associated health care needs, provide health planners and policy makers with a more detailed picture of the future elderly population than available heretofore.

Conclusion

Using multistate analysis, we have calculated expectations of active lite for individuals aged 70 and over in several different statuses of well-being. Our findings have extended past research by providing information on active life through age 90, by providing estimates for the United States rather than for a particular state or region, and by presenting estimates for three different functional statuses. Although many analysts are concerned about the number of elderly who leave the independent status, our findings indicate that many individuals are living long, active lives, and that many individuals who become dependent are dependent only temporarily and then return to an independent status.

Past theories of mortality have tended to view populations as being homogeneous. Only recently have researchers discussed the heterogeneity exhibited by the elderly in their health patterns. We have conceptualized the elderly population as a heterogeneous one by defining two and then three functional statuses and by calculating different life expectancies for each status-specific population. Our results reveal that there is indeed substantial heterogeneity with regard to health within the elderly population.

The time interval between the initial interview and the reinterview for the LSOA was two years. Therefore, we have based our calculations and transitions on a two-year interval. This interval provides the advantage of a relatively short time span but one that is long enough to capture transitions. Most life-table calculations are based on one-year intervals and assume constant distributions of risk within the interval. By using a two-year interval, in which the risk of mortality is not constant but increases, we undoubtedly introduce a degree of underestimation in our life-expectancy calculations. But such a bias is likely to be small. Nevertheless, it would be illuminating to estimate the effect of calculating similar active life expectancies with shorter intervals.

Our results supplement and extend previous studies of active life expectancies. Katz et al. (1983) and Rogers, Rogers, and Branch (1989)

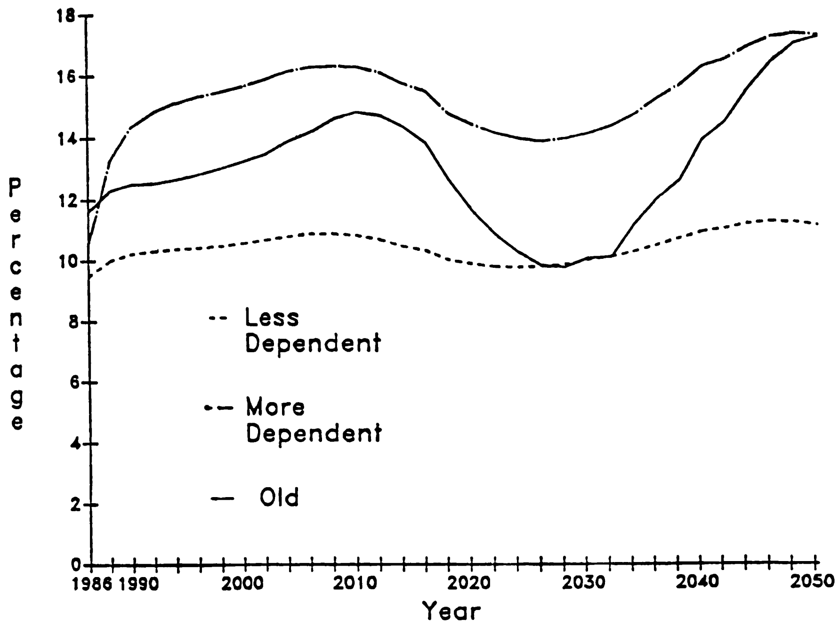


FIG. 9. Proportion of the population aged 70 and over that is less dependent, more dependent, and older (aged 86 and over): United States, 1990–2050. *Source:* Calculations based on LSOA data (U.S. Department of Health and Human Services 1988).

have examined active life among the Massachusetts elderly. Katz and his colleagues based their analysis on the unistate life-table technique. Rogers and his colleagues applied multistate analysis to the same data base, but to smooth the life expectancy curves they applied mortality estimates from the LSOA data to the Massachusetts data. Both sets of researchers based their estimates on four rather than seven ADLs. Although our United States results are not directly comparable with the results obtained with the Massachusetts data, such comparisons nevertheless provide some interesting insights. Multistate transitions of active life statuses for Massachusetts and the United States appear to be similar. Generally, individuals in Massachusetts can expect greater proportions of their lives to be active; this difference possibly reflects differences in the categorization of dependency (using four versus seven ADLs), as well as variations in data quality, date of interview, population health, or sample size.

Active life, as we have measured it here, identifies those individuals who are dependent in their activities of daily living. These individuals require help in their ADLs. Therefore, we have examined dependency and not difficulty. Although we know there are more individuals who have difficulty in performing ADLs, we do not know what the life expectancies of such individuals might be, nor do we know what the transitions are between "difficulty" and "ease" in performing ADLs. Similarly, we have selected ADLs rather than IADLs (instrumental activities of daily living), which measure such factors as ability to prepare meals, manage money, and use the telephone. An extension of our analysis in this direction would provide yet another and possibly more sensitive measure of the elderly population's range of participation in society. Further research will examine these issues and jointly examine ADL and IADL measures.

We have shown that even though women live longer than men, men live a greater proportion of their lives in an active status. Unlike Katz et al. (1983), however, we have found that women can expect to live more active years than men. Therefore, women compared to men live longer and live longer active lives, but they also live longer lives with dependence (see also Bebbington 1988; Manton 1988).

As mortality declines, the "quality" and vitality of the elderly population increases in relative policy importance. Controversy still surrounds the issues of whether declining elderly mortality results in additional years of health. Some researchers contend that as mortality declines, morbidity is compressed into more advanced ages (Fries 1983, 1989). Fries assumes that people eventually will be free of chronic diseases until the very end of life. Although life expectancy may not increase substantially, morbidity and disability will be delayed, primarily because of improving personal health care practices. Clearly, future trends are unknown, but current evidence tends to show that, as increasing members of elderly have moved to older ages because of reduced mortality, morbidity and disability has increased (see, for example, Myers and Manton 1984; Schneider and Brody 1983; Verbrugge 1984; Wilkins and Adams 1983). (For an excellent exchange regarding these issues, see *Gerontologica Perspecta* 1987.) Answers to such questions require data that interrelate independence, dependence, and mortality over several points in time. Our findings establish baseline functional status estimates, transitions, and projections. As such, our projections provide a demographic account of what the future might be like, if current rates continue.

Our projections assume constant mortality by functional status and no migration. (Nevertheless, our data implicitly include further mortality declines and positive net migration because we have incorporated the U.S. Census Bureau's middle series estimates for those individuals who enter age 70 into our model.) If, in the future, the life expectancy and immigration of the elderly increases, our projections will have underestimated the size of the elderly population. Therefore, we may have painted a more pessimistic picture of future survival, but a more optimistic picture of the absolute magnitude of future health and social service demands. Although there is no way of knowing at present which scenario is correct, we should realize that future changes in elderly mortality or migration will affect projections of the elderly.

Our projections have attributed an active-life-status distribution and transition of the current elderly for the soon-to-be elderly at each year of the projection period. Because of data limitations, we were forced to assume that the functional-status distribution of new elderly will not change. This assumption may prove correct overall, but may bias health measures of particular age groups. For instance, the group aged 65 to 74 will most likely see increasing active life in the future. On the other hand, the oldest old, at ages 85 and over, may see little change in the distribution of their functional status. If this occurs, many elderly will be faced with longer lives, but lives that end in a prolonged inactive state. Moreover, we as a society will be faced with an increasing number of frail and quite dependent very old individuals who disproportionately require advanced and constant health, economic, and social services. For example, Guralnik, Yanagishita, and Schneider (1988) illustrate that, if current rates of nursing-home use continue, the number of individuals aged 85 and over in nursing homes will jump from the current 600,000 to between 2.8 and 5 million by 2040. In 1987, less than 10 percent of the elderly were aged 85 and over; in the year 2080, almost 1 out of every 4 elderly will be aged 85 and over (U.S. Bureau of the Census 1989). Such changes in the age distribution of the elderly will undoubtedly affect the health, housing, and social programs designed for them.

The LSOA began with noninstitutionalized individuals in 1984, but included individuals who became institutionalized in 1986. Because institutionalized elderly were not included in both years, we could not calculate transitions from, say, institutionalization to independency. Further, the exclusion of institutionalized individuals from the 1984 sample may depress our transition probabilities from independence to dependence and increase our transition probabilities from dependence to independence. Clearly, there is a need to employ our methodology to other data sets that allow transitions from institutionalization to independence and dependence.

The aging Baby Boom generation will produce a surge in the size of the older population, thus creating an "elderly boom" generation (Barberis 1981:3). This elderly boom will create a peak in the size of the older population around the year 2035. This increased size in the older population will increase demands on health care services. Nevertheless, if policy makers are concerned with dependency and not solely with population size, then they should be aware of the increasing needs of and demands by the elderly 20 years before the elderly boom. For example, in the year 2010, more than 30 percent of all elderly are projected to be dependent. Thus, although we should prepare for the changes that will occur in the decade of 2030, additional, and perhaps more crucial, preparations are needed two decades earlier. Moreover, we should not become complacent once we meet the demands of the year 2035. Although the size of the elderly population will decline for some time, the age and dependency of the elderly population will continue to increase. Our data, then, have provided more insight into the critical periods for the elderly population as a whole and have highlighted a new set of issues that we must understand and use in preparing current and future health, social, and economic services for the elderly.

We have calculated active life expectancies for the elderly in the United States by two and three statuses, and for males and females. Further, we have projected the population distribution by functional status to the year 2050. Such analyses provide us with baseline rates for the United States, give us active life expectancies and their transitions, and allow us to speculate upon what the future active life of the elderly might be. Specifically, we have found that the elderly are indeed a heterogeneous subpopulation, that they can expect to live a substantial amount of time in an active state, and that most elderly can expect to live long active lives. Our projections have shown that the elderly population will grow in size until 2035. Then, even though the total number of elderly may decline, because of the aging of the elderly, the proportion of the dependent elderly may increase. Although policy analysts are concerned with future changes, they may be too farsighted; some of the problems we envision will develop within two to three, not five, decades. The time horizon for planning for these changes may be shorter than we previously assumed.

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