### Title
Maintaining mobility in late life. I. Demographic characteristics and chronic conditions.




### Journal
American Journal of Epidemiology, 137(8)

### ISSN
0002-9262



### Authors
Guralnik, JM
LaCroix, AZ
Abbott, RD
et al.



### Publication Date
1993-04-15

### DOI
10.1093/oxfordjournals.aje.a116746

Peer reviewed

American Journal of Epidemiology
Vol. 137, No. 8


# Maintaining Mobility in Late Life

## I. Demographic Characteristics and Chronic Conditions

Jack M. Guralnik,[1] Andrea Z. LaCroix,[2] Robert D. Abbott,[3] Lisa F. Berkman,[4] Suzanne Satterfield,[5] Denis A. Evans,[6] and Robert B. Wallace[7]

To assess the role of demographic factors and chronic conditions in maintaining mobility in older persons, this study utilized longitudinal data collected as part of the Established Populations for Epidemiologic Studies of the Elderly between 1981 and 1987 on 6,981 men and women aged 65 years and older in East Boston, Massachusetts; Iowa and Washington counties, Iowa; and New Haven, Connecticut. Results are presented for those who at baseline reported intact mobility, defined as the ability to climb stairs and walk a half mile without help, and who were followed annually for up to 4 years for changes in mobility status. Age, income, education, and chronic conditions present at baseline and occurring during follow-up were evaluated for their association with loss of mobility. Over the follow-up period, 55.1% of subjects maintained mobility, 36.2% lost mobility, and 8.7% died without evidence of mobility loss prior to death. In both men and women, increasing age and lower income levels were associated with increased risk of losing mobility, even after controlling for the presence of chronic conditions at baseline. After adjustment for age, income, and chronic conditions, lower education levels were a significant risk factor for mobility loss in men, but not in women. Baseline reports of previous heart attack, stroke, high blood pressure, diabetes, dyspnea, and exertional leg pain were associated with small but significant risks for mobility loss. There was a stepwise increase in the risk of mobility loss according to the number of chronic conditions present at baseline that was very consistent between men and women. The occurrence during the study of a new heart attack, stroke, cancer, or hip fracture was associated with a substantially greater risk of mobility loss than was associated with the presence of these conditions at baseline. *Am J Epidemiol* 1993;137:845–57.

activities of daily living; aged; chronic disease; demography; education; income; prospective studies

The impact that the future aging population will have on the health care system and on society in general will be related in large part to the level of functioning, loss of in-

Received for publication April 29, 1992, and in final form November 25, 1992.

[1] Epidemiology, Demography, and Biometry Program, National Institute on Aging, Bethesda, MD.
[2] Center for Health Studies, Group Health Cooperative of Puget Sound, and Department of Epidemiology, University of Washington, Seattle WA.
[3] Division of Biostatistics, Department of Medicine, University of Virginia School of Medicine, Charlottesville, VA
[4] Department of Epidemiology, Yale University School of Medicine, New Haven, CT.
[5] Channing Laboratory, Department of Medicine, Harvard Medical School, and the East Boston Neighborhood Health Center, Boston, MA.
[6] Center for Research on Health and Aging, Rush-Presbyterian-St. Luke's Medical Center, Chicago, IL.
[7] Department of Preventive Medicine and Environmental Health, University of Iowa, Iowa City, IA.
Reprint requests to Dr. Jack M. Guralnik, National Institute on Aging, 7201 Wisconsin Ave., Room 3C-309, Bethesda, MD 20892.

Supported by contracts N01-AG-0-2105, N01-AG-0-2106, N01-AG-0-2107 with the National Institute on Aging, National Institutes of Health.
The authors acknowledge the important contributions of Ase Sewall to the analysis of these data.

dependence, and need for long-term care of those living to the oldest ages (1). In an attempt to understand factors associated with both disability and retention of higher levels of functioning in older persons, a number of studies have approached this important issue by using data from a variety of available prospective studies (2–9).

Previous studies have added to our understanding of factors associated with functional outcomes in older persons, but a number of their methodological aspects may be improved upon. These studies typically employed various definitions of functioning that used a series of questionnaire items to create composite, multidimensional outcome measures that may make it difficult to understand the effect of risk factors on specific aspects or domains of functioning. Some did not exclude those with poor functional status at baseline. The available data in previous studies restricted assessment of the functional outcome to a single point in time after baseline. Such an approach may miss important but transient changes in functional status. Furthermore, these studies did not consider the occurrence of new disease events during the course of follow-up that may be major determinants of functional loss.

In this study, three cohorts from the Established Populations for Epidemiologic Studies of the Elderly were evaluated to assess the role of demographic characteristics and chronic conditions in maintaining mobility in those aged 65 years and older. In the accompanying paper by LaCroix et al. (10), the role of behavioral risk factors on maintaining mobility is evaluated. These studies have a number of methodological strengths. The functional outcome being investigated is mobility, defined as the ability to walk some distance and climb stairs. This outcome was chosen because of its critical importance to older people in the preservation of independence and high quality of life and because of its simplicity, making interpretation of results clearer than for many previous studies. Data from the annual follow-up interviews with study participants allowed for a more complete assessment of the persistence of high function over time. Moreover, this study distinguishes between prevalent chronic conditions at baseline and the occurrence of new disease events during follow-up, such as heart attack, stroke, and hip fracture. Finally, data from this study are from three community-based prospective studies that provide the largest sample available to date for determining the predictors of functional loss and give the opportunity to assess consistency of results across the three communities.

## MATERIALS AND METHODS

### Study populations

Data from older adults in three communities of the Established Populations for Epidemiologic Studies of the Elderly were studied for this report. The Established Populations for Epidemiologic Studies of the Elderly are collaborative longitudinal studies of men and women aged 65 years and older living in the community, initiated and funded by the Epidemiology, Demography, and Biometry Program of the National Institute on Aging. Baseline household interviews were conducted between 1981 and 1983 in East Boston, Massachusetts; New Haven, Connecticut; and Iowa and Washington counties in rural Iowa. The details of the methods used in the surveys have been described previously (11).

Briefly, trained interviewers conducted the initial household interview to collect information on demographic characteristics, medical history, the use of prescription and nonprescription drugs, health behaviors, and functional status. Surrogate or proxy informants were interviewed for those subjects who were unable to respond for themselves (4.4 percent). Interviews were sought from all people aged 65 years and older in the community in East Boston and rural Iowa; initial interviews were completed with 3,809 subjects in East Boston (85 percent of eligible respondents) and 3,673 subjects in rural Iowa (80 percent of eligible respondents). The study population in New Haven was drawn from a stratified random sample defined according to type of housing (public

or private), with an oversampling of men. Initial interviews were completed with 2,812 New Haven subjects (82 percent of eligible respondents).

During a 4-year follow-up period completed in 1987, updated information was ascertained at annual interviews on functional status, the occurrence of selected medical conditions in the previous year, and nursing home admissions. These were conducted by telephone in the first, second, and fourth years of follow-up and by an in-person household interview in the third year of follow-up. Vital status of all participants during follow-up was ascertained through information collected at the annual interview and by local surveillance mechanisms such as monitoring obituary notices and state vital statistics records. Ascertainment of vital status was nearly 100 percent complete at all sites. Among those initially interviewed, the response rates for the follow-up interviews were above 90 percent in each community.

### Classification of mobility status at baseline and follow-up

Mobility was classified using two questions modified from the Rosow-Breslau functional status questionnaire (12): Are you able to walk up and down stairs without help? Are you able to walk a half mile without help? Those answering yes to both questions at baseline were classified as mobile, while those answering no to either or both questions were classified as having impaired mobility.

Those who were mobile at baseline were considered to have maintained mobility during follow-up if they responded yes to both mobility questions at each annual follow-up interview. If data on mobility were missing at a single interview but the respondents gave affirmative answers to both questions at all subsequent annual interviews, they were considered to have maintained mobility. For the purposes of the analyses presented here, respondents were considered to have lost mobility if they or their proxies reported a need for help in stair climbing or in walking a half mile at any of the follow-up interviews.

At baseline, 2,622 (68.8 percent) of those in East Boston, 2,677 (72.9 percent) of those in Iowa, and 1,928 (68.6 percent) of those in New Haven were classified as mobile. Data on mobility were missing for 327 persons (3.2 percent) over all three sites. Of those 7,227 individuals classified as mobile at baseline, 246 (3.4 percent) had data missing during follow-up on mobility or vital status, leaving 6,981 persons in this analysis. During the 4 years of follow-up, mobility was maintained by 3,847 persons (55.1 percent). Mobility was lost by 2,526 (36.2 percent), and in 608 (8.7 percent) death occurred with no evidence of loss of mobility prior to death. In the three communities, mobility was maintained by 56.8 percent in East Boston, 62.4 percent in Iowa, and 42.5 percent in New Haven.

### Risk factors for maintaining mobility

From the baseline interview, annual income was classified as less than $5,000, $5,000-$9,999, or $10,000 and greater. Respondents were asked for the highest grade or year of school they had completed. Educational attainment was classified as 8 years or less, 9–12 years, or more than 12 years.

At baseline, history of heart attack, stroke, cancer, and hip fracture was considered positive if the participant had ever been told of the presence of this condition by a health professional and had been hospitalized overnight or longer for the condition. Participants were further queried about the presence of diabetes, high blood pressure, arthritis or joint pain, pain in either leg on walking, and shortness of breath that required the individual to stop and rest (dyspnea). Angina was considered present if there was chest pain, pressure, or heaviness in the chest brought on by walking up a hill or on level ground, a definition previously found to be prognostically equivalent to the full Rose questionnaire definition of angina (13).

Data on income were missing for 14.9 percent of subjects and on education for 2.0 percent. In multivariate models, separate in-

dicator variables for missing data were included so that those subjects with missing data would be retained in the analysis. From 4.1 to 5.6 percent of participants were missing data on arthritis, leg pain on walking, shortness of breath, and angina, and for these subjects separate indicator variables for missing status were also used in multivariate analyses. All other chronic conditions had less than 1 percent missing data, and those with missing data on these variables were imputed as not having the condition.

Newly occurring conditions were assessed at each follow-up interview by asking participants if, since the last interview, they had been told by a health professional that they had had a heart attack or stroke or that they had cancer, diabetes, and hip fracture. Heart attack, stroke, cancer, and hip fracture were considered to be present only if participants also responded that they had spent overnight or longer in the hospital for this condition.

### Statistical analysis

To help describe the relation between important observations that were made at study enrollment and the probability of remaining mobile, subjects who were mobile at baseline were followed for up to 4 years for evidence of loss of mobility. Proportions that remained mobile were then estimated according to demographic characteristics and the presence and absence of each chronic condition. All rates were calculated separately for men and women, and when derived by levels of factors other than age, rates were age-adjusted (14).

To evaluate the independent effect of the various demographic characteristics and each chronic condition on the incidence of immobility, proportional hazards regression models were used (15, 16). These models evaluated the effect of independent variables on time to loss of mobility. Those surviving with no evidence of mobility loss were censored at 4 years, those dying with no evidence of mobility loss were censored at the time of their death, and those lost to follow-up were censored after their last interview. Regression models were estimated separately by study site and separately for men and women. Overall estimates of relative risk were calculated from proportional hazards regression models stratified by community, using the BLOCK option of the SAS PHGLM procedure to obtain summary estimates across the communities (17). The impact of multiple chronic conditions, or comorbidity, on loss of mobility was evaluated in proportional hazards models that employed four indicator variables (indicating the presence of one, two, three, or four or more conditions) and used "no conditions" as the reference category.

Change in the status of five chronic conditions in the course of follow-up was modeled as a time-dependent risk factor. Since follow-up assessments of new disease events occurred on a yearly basis, the time an event occurred could not be determined exactly. As a result, the effect of the development of a new condition was updated once a year, which meant that new baselines and underlying hazard functions were established at the beginning of each year of follow-up.

Estimates of relative risk and 95 percent confidence intervals were derived based on the corresponding regression coefficient for each demographic characteristic and chronic condition. Relative risks were estimated separately for conditions that were prevalent at the baseline interview and for those conditions that developed in the course of follow-up. All tests of significance were two-tailed.

## RESULTS

Table 1 shows the sample size, demographic characteristics, prevalence of chronic conditions at baseline, and occurrence of chronic conditions during follow-up for men and women at each site who were classified as mobile at baseline and had follow-up data on mobility and vital status. The mean age was 73.1 years, with a range of 65–103.

Table 2 shows the percentage remaining mobile during follow-up according to age group and the age-adjusted percentage remaining mobile during follow-up according

**TABLE 1.** ***Demographic characteristics and prevalence of chronic conditions at baseline, and occurrence of chronic conditions during follow-up (percent), Established Populations for Epidemiologic Studies of the Elderly, 1981–1987***

| | East Boston, MA | | Iowa | | New Haven, CT | |
|---|---|---|---|---|---|---|
| | Men ($n$ = 1,077) | Women ($n$ = 1,407) | Men ($n$ = 1,085) | Women ($n$ = 1,544) | Men ($n$ = 884) | Women ($n$ = 984) |
| Demographic characteristics (%) | | | | | | |
| Age (years) | | | | | | |
| 65–74 | 69.0 | 71.9 | 64.2 | 60.4 | 61.1 | 61.1 |
| 75–84. | 25.3 | 25.0 | 30.1 | 34.8 | 30.8 | 32.4 |
| ≥85 | 5.8 | 3.1 | 5.6 | 4.8 | 8.1 | 6.5 |
| Income (dollars)* | | | | | | |
| ≥$10,000 | 28.4 | 14.6 | 47.2 | 31.7 | 29.4 | 14.4 |
| $5,000–9,999 | 48.4 | 43.3 | 25.1 | 30.1 | 39.3 | 32.9 |
| <$5,000 | 11.2 | 29.4 | 9.6 | 16.9 | 21.5 | 40.4 |
| Education (years)* | | | | | | |
| >12 | 9.0 | 5.6 | 14.8 | 22.5 | 17.9 | 13.3 |
| 9–12 | 42.2 | 48.6 | 40.0 | 45.9 | 32.9 | 36.1 |
| ≤8 | 44.5 | 42.4 | 44.8 | 31.0 | 48.1 | 48.5 |
| Baseline chronic conditions (% with condition) | | | | | | |
| Heart attack | 12.5 | 5.8 | 18.0 | 5.5 | 13.5 | 7.0 |
| Stroke | 4.9 | 1.6 | 5.0 | 4.2 | 5.0 | 3.4 |
| Cancer | 10.6 | 16.6 | 12.6 | 13.3 | 10.5 | 15.5 |
| Diabetes | 14.9 | 10.8 | 10.1 | 7.9 | 11.1 | 10.4 |
| High blood pressure | 32.0 | 45.1 | 31.5 | 45.3 | 36.3 | 48.2 |
| Hip fracture | 2.3 | 1.4 | 1.7 | 3.4 | 2.7 | 2.9 |
| Angina | 8.5 | 9.7 | 9.1 | 6.3 | 8.8 | 8.2 |
| Dyspnea | 24.2 | 28.1 | 29.2 | 19.4 | 27.8 | 26.6 |
| Arthritis | 25.0 | 30.9 | 55.6 | 56.9 | 28.4 | 46.5 |
| Leg pain | 28.4 | 32.6 | 15.5 | 13.9 | 29.4 | 29.7 |
| Follow-up conditions (% reporting new occurrence over 4 years) | | | | | | |
| Heart attack | 8.6 | 4.5 | 4.4 | 3.0 | 6.1 | 4.4 |
| Stroke | 4.6 | 3.6 | 6.3 | 3.4 | 3.5 | 3.9 |
| Cancer | 11.3 | 6.8 | 11.1 | 6.4 | 7.7 | 5.5 |
| Diabetes | 5.7 | 4.6 | 4.3 | 3.2 | 2.7 | 3.8 |
| Hip fracture | 1.9 | 1.4 | 1.1 | 2.7 | 1.1 | 2.7 |

* Total does not add to 100% because of missing data.

to income, education, and the presence of chronic conditions. There was a strong age gradient in the maintenance of mobility at each site, with those aged 75–84 and 85 years and older showing significantly less probability of remaining mobile. Compared with higher income, low income was associated with significantly lower rates of maintaining mobility at all sites, as was middle-income level in men in East Boston and New Haven and women in Iowa and New Haven. Compared with those with more than 12 years of education, those with less than 8 years were significantly less likely to maintain mobility, except for women in New Haven. For the chronic conditions, a significant increase in the percentage of men and women at all sites who maintained mobility was associated with the absence of heart attack, diabetes, high blood pressure, angina, dyspnea, and

**TABLE 2. Age-adjusted percentage remaining mobile over 4 years according to demographic characteristics and chronic conditions at baseline, Established Populations for Epidemiologic Studies of the Elderly, 1981–1987**

| | East Boston, MA | | Iowa | | New Haven, CT | |
|---|---|---|---|---|---|---|
| | Men | Women | Men | Women | Men | Women |
| Demographic characteristics | | | | | | |
| Age (years) | | | | | | |
| 65–74† | 66 | 64 | 73 | 73 | 56 | 50 |
| 75–84 | 40* | 42* | 50* | 49* | 33* | 29* |
| ≥85 | 21* | 30* | 23* | 16* | 7* | 9* |
| Income (dollars) | | | | | | |
| ≥$10,000† | 63 | 65 | 69 | 71 | 54 | 53 |
| $5,000–9,999 | 53* | 55 | 59 | 61* | 43* | 43* |
| <$5,000 | 49* | 51* | 56* | 58* | 40* | 39* |
| Education (years) | | | | | | |
| >12† | 67 | 62 | 74 | 69 | 57 | 50 |
| 9–12 | 56 | 55* | 63 | 62* | 45* | 42 |
| ≤8 | 53* | 54* | 60* | 61* | 42* | 41 |
| Chronic conditions | | | | | | |
| Heart attack | | | | | | |
| Yes | 40* | 38* | 49* | 46* | 31* | 27* |
| No† | 58 | 55 | 66 | 64 | 48 | 43 |
| Stroke | | | | | | |
| Yes | 36* | 37* | 45* | 46* | 28 | 26 |
| No | 56 | 55 | 64 | 64 | 47 | 43 |
| Cancer | | | | | | |
| Yes | 52 | 55 | 60 | 64 | 42 | 43 |
| No | 56 | 54 | 64 | 63 | 46 | 42 |
| Diabetes | | | | | | |
| Yes | 44* | 41* | 51* | 50* | 34* | 30* |
| No | 57 | 56 | 65 | 64 | 47 | 44 |
| High blood pressure | | | | | | |
| Yes | 51* | 49* | 59* | 58* | 41* | 38* |
| No | 58 | 59 | 65 | 67 | 48 | 47 |
| Hip fracture | | | | | | |
| Yes | 46 | 44 | 55 | 53* | 37 | 32 |
| No | 56 | 55 | 63 | 63 | 46 | 43 |
| Angina | | | | | | |
| Yes | 40* | 37* | 50* | 46* | 31* | 26* |
| No | 57 | 56 | 66 | 65 | 47 | 44 |
| Dyspnea | | | | | | |
| Yes | 41* | 42* | 53* | 51* | 33* | 31* |
| No | 60 | 59 | 70 | 67 | 51 | 47 |
| Arthritis | | | | | | |
| Yes | 54 | 49* | 64 | 62 | 44 | 39* |
| No | 56 | 57 | 66 | 68 | 46 | 46 |
| Leg pain | | | | | | |
| Yes | 46* | 43* | 55* | 50* | 37* | 31* |
| No | 59 | 60 | 67 | 66 | 50 | 47 |

* Significantly different from reference group, $p < 0.05$.
† Reference group; for chronic conditions, reference group does not have the condition.

exertional leg pain. The absence of stroke was significantly associated with higher rates of maintaining mobility in men and women in two of the three sites. Arthritis was associated with maintenance of mobility in women in only two sites. Men and women with no history of hip fracture had higher rates of maintaining mobility at all sites, but this was statistically significant only for women in Iowa. History of cancer at baseline was not associated with maintaining mobility.

To assess the independent effects of variables examined in table 2, demographic characteristics and the eight chronic conditions that were significant predictors of mobility in at least two sites were entered into a proportional hazards model. Results are shown for each site separately, and a community-stratified summary is presented (table 3). Results were quite consistent across sites. The community-stratified summary showed a twofold increase in risk of losing mobility for each 10-year increase in age. Compared with those with high income, both men and women with low or medium incomes were 1.3–1.5 times as likely to lose mobility. Even after adjustment for income, men with low and medium levels of education continued to have 1.5 times the risk of losing mobility as did men with a high level of education. There was no increased risk according to educational status in women. When all variables in the model were controlled for, there were modest increases in relative risk of losing mobility (relative risk = 1.5 or less) for all chronic conditions except arthritis. The risk was significantly elevated in the community-stratified analysis for heart attack, stroke, high blood pressure, diabetes, dyspnea, and exertional leg pain.

At each site there was a stepwise increase in the risk of losing mobility with increasing number of chronic conditions (table 4). Overall, those persons who were mobile at baseline but had four or more conditions were nearly three times as likely to lose mobility as those with no conditions at baseline.

The impact of conditions occurring during follow-up was examined by evaluating the associations of new heart attack, stroke, cancer, and hip fracture events and first report of diabetes with loss of mobility at any time after the report of those events (table 5). The strongest predictors of mobility loss were for new hip fracture and stroke events. Heart attack and cancer also were significantly associated with loss of mobility. Newly diagnosed diabetes showed no association with the mobility outcome. This model also incorporated variables representing the presence of these five conditions at baseline. Those baseline conditions that were predictive of mobility loss (table 3) had similar relative risks in the model shown in table 5 and continued to be significantly associated with loss of mobility even after controlling for new events.

## DISCUSSION

The ability to remain mobile is fundamental to overall functioning and the maintenance of independence in older persons. For those who were mobile at baseline and who, therefore, were included in these analyses, the loss of mobility over a relatively short follow-up period is an important change in functional status with potentially catastrophic consequences. Other research has shown that gait and balance problems are important predictors of falls in older persons (18, 19) and that impaired mobility, defined in the same way as in this study, is a predictor of hip fracture (20). In a community-based study, use of an ambulation aid was among the most important predictors of institutionalization (21). In our study cohort, those with impaired mobility at baseline had an eightfold higher prevalence of limitations in activities of daily living, threefold greater prevalence of two or more chronic conditions, and, during follow-up, had significantly higher rates of both institutionalization and mortality than did those who were mobile (data not shown).

This study demonstrates that increasing age, low income and education, and specific chronic conditions are predictive of an increased risk of losing mobility. Income and

**TABLE 3. Relative risks relating demographic characteristics and baseline chronic conditions to loss of mobility, Established Populations for Epidemiologic Studies of the Elderly, 1981–1987***

| | East Boston, MA | | | | Iowa | | | | New Haven, CT | | | | Community-stratified summary | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | Women | | Men | | Women | | Men | | Women | | Men | | Women | |
| | RR† | 95% CI† | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI |
| Demographic characteristics | | | | | | | | | | | | | | | | |
| Age (10-year increase) | 1.9 | 1.6–2.3 | 1 7 | 1.5–1.9 | 2.5 | 2 1–3.0 | 2 4 | 2.1–2.8 | 1.8 | 1.5–2 1 | 1.9 | 1.6–2 1 | 2 0 | 1 8–2.2 | 1.9 | 1 8–2.1 |
| Income (dollars) | | | | | | | | | | | | | | | | |
| <$5,000 vs. ≥$10,000 | 1.6 | 1.1–2.4 | 1.3 | 1.0–1.8 | 1.2 | 0.8–1 8 | 1.4 | 1.1–1.9 | 1.5 | 1 1–2.1 | 1.8 | 1 3–2.4 | 1.5 | 1.2–1.8 | 1.5 | 1.2–1.7 |
| $5,000–9,999 vs. ≥$10,000 | 1.4 | 1.0–1 9 | 1.3 | 1.0–1.8 | 1.3 | 0.9–1 7 | 1.2 | 1.0–1.5 | 1.2 | 0.9–1.7 | 1.1 | 0.9–1.3 | 1.3 | 1 1–1.5 | 1.3 | 1.1–1 6 |
| Education (years) | | | | | | | | | | | | | | | | |
| ≤8 vs >12 | 1.4 | 0.8–2.2 | 1.6 | 1.0–2 7 | 1.3 | 0 9–2.0 | 1 2 | 1.0–1.6 | 1 6 | 1.1–2.3 | 0.8 | 0 6–1 1 | 1.5 | 1.2–1.9 | 1 1 | 1.0–1.4 |
| 9–12 vs. >12 | 1.3 | 0.8–2 0 | 1.6 | 1.0–2.6 | 1 4 | 0.9–2 2 | 1.2 | 1.0–1.6 | 1 6 | 1 1–2.4 | 0 7 | 0 6–1 0 | 1.5 | 1.2–1.9 | 1.1 | 1.0–1.3 |
| Baseline chronic conditions | | | | | | | | | | | | | | | | |
| Heart attack | 1.2 | 0.9–1 7 | 1.3 | 0.9–1.8 | 1 1 | 0.8–1 5 | 1.1 | 0 8–1.5 | 1.7 | 1 3–2.3 | 1 3 | 1.0–1.8 | 1.3 | 1 1–1.6 | 1.2 | 1.0–1.5 |
| Stroke | 1.3 | 0 8–2.0 | 1 9 | 1.1–3.1 | 1.9 | 1 3–2.9 | 1 4 | 1.0–2.0 | 1.3 | 0.8–2.0 | 1.0 | 0.7–1 6 | 1.5 | 1.2–1.9 | 1 4 | 1.1–1.8 |
| High blood pressure | 1.2 | 1.0–1.6 | 1 0 | 0.9–1.2 | 1.3 | 1 0–1.6 | 1.3 | 1.1–1.5 | 1.2 | 1.0–1.5 | 1.2 | 1.0–1.5 | 1.2 | 1.1–1.4 | 1.2 | 1.1–1.3 |
| Diabetes | 1.2 | 0.9–1.7 | 1 6 | 1.3–2.0 | 1.3 | 0.9–1.9 | 1.3 | 1.0–1.8 | 1 4 | 1.0–1.8 | 1.2 | 1.0–1.6 | 1.3 | 1.1–1.5 | 1.4 | 1.2–1.6 |
| Angina | 1.2 | 0.8–1.8 | 1.3 | 1.0–1 7 | 1 2 | 0.8–1.8 | 1.2 | 0.9–1 7 | 1 1 | 0.9–1 4 | 1 0 | 0.8–1.4 | 1 2 | 0 9–1.5 | 1.2 | 1.0–1 4 |
| Dyspnea | 1.8 | 1.4–2.4 | 1 4 | 1.2–1.7 | 1.5 | 1.2–2.0 | 1.6 | 1.3–1.9 | 1.3 | 1.0–1 6 | 1.3 | 1.1–1.6 | 1 5 | 1.3–1.7 | 1.4 | 1.3–1.6 |
| Exertional leg pain | 1.3 | 1.0–1 7 | 1 3 | 1 1–1.5 | 1.5 | 1.1–2.1 | 1.6 | 1 3–2.0 | 1.4 | 1.1–1.8 | 1.4 | 1.2–1 7 | 1.4 | 1.2–1.6 | 1.4 | 1.3–1.6 |
| Arthritis | 0 9 | 0.7–1.2 | 1 3 | 1.1–1.6 | 1.2 | 0.9–1.5 | 1 0 | 0.8–1.2 | 1.1 | 0.9–1.5 | 1.1 | 0.9–1.3 | 1.1 | 0.9–1 2 | 1.1 | 1.0–1.3 |

* Based on proportional hazards models, adjusted for demographic characteristics and all chronic conditions.
† RR, relative risk; CI, confidence interval.

**TABLE 4. Relative risks (compared with having no conditions) relating the number of chronic conditions to loss of mobility, Established Populations for Epidemiologic Studies of the Elderly, 1981–1987***

| No. of conditions | East Boston, MA | | | | Iowa | | | | New Haven, CT | | | | Community-stratified summary | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | Women | | Men | | Women | | Men | | Women | | Men | | Women | |
| | RR† | 95% CI† | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI |
| 1 | 1.6 | 1.1–2.3 | 1.5 | 1.2–2.0 | 1.0 | 0.7–1.5 | 1.3 | 1.0–1.7 | 1.5 | 1.1–2.1 | 1.2 | 0.9–1.6 | 1.4 | 1.1–1.7 | 1.3 | 1.1–1.6 |
| 2 | 2.1 | 1.4–2.9 | 1.7 | 1.3–2.2 | 1.3 | 0.9–1.9 | 1.6 | 1.2–2.1 | 1.8 | 1.3–2.6 | 1.6 | 1.2–2.1 | 1.7 | 1.4–2.1 | 1.6 | 1.4–1.9 |
| 3 | 2.6 | 1.8–3.9 | 2.7 | 2.0–3.6 | 1.8 | 1.2–2.6 | 2.1 | 1.5–2.9 | 2.9 | 2.0–4.3 | 2.2 | 1.7–3.0 | 2.5 | 2.0–3.1 | 2.3 | 1.9–2.7 |
| ≥4 | 3.3 | 2.2–5.0 | 3.4 | 2.5–4.6 | 2.2 | 1.4–3.4 | 2.8 | 2.0–3.9 | 3.2 | 2.1–4.7 | 2.3 | 1.7–3.2 | 2.9 | 2.3–3.7 | 2.7 | 2.3–3.3 |

* Based on proportional hazards models, adjusted for age.
† RR, relative risk; CI, confidence interval.

**TABLE 5. Relative risks relating conditions that occurred during follow-up period to loss of mobility, Established Populations for Epidemiologic Studies of the Elderly, 1981–1987***

| Newly occurring conditions | East Boston, MA | | | | Iowa | | | | New Haven, CT | | | | Community-stratified summary | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | Women | | Men | | Women | | Men | | Women | | Men | | Women | |
| | RR† | 95% CI† | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI | RR | 95% CI |
| Heart attack | 1.7 | 1.1–2.7 | 2.3 | 1.5–3.5 | 2.1 | 1.2–3.5 | 1.9 | 1.1–3.2 | 2.1 | 1.4–3.2 | 2.2 | 1.5–3.4 | 2.0 | 1.5–2.6 | 2.2 | 1.7–2.8 |
| Stroke | 2.7 | 1.7–4.3 | 3.0 | 2.0–4.5 | 2.9 | 1.9–4.3 | 2.6 | 1.7–3.8 | 2.4 | 1.4–4.0 | 2.2 | 1.3–3.6 | 2.7 | 2.0–3.4 | 2.6 | 2.0–3.3 |
| Cancer | 1.2 | 0.8–2.0 | 2.1 | 1.5–3.1 | 2.6 | 1.8–3.6 | 2.2 | 1.6–3.2 | 1.8 | 1.2–2.7 | 1.7 | 1.2–2.5 | 1.8 | 1.5–2.3 | 2.0 | 1.6–2.5 |
| Diabetes | 1.1 | 0.7–1.6 | 1.1 | 0.8–1.6 | 1.2 | 0.7–2.1 | 1.1 | 0.6–1.9 | 0.5 | 0.3–0.9 | 1.1 | 0.7–1.6 | 0.9 | 0.7–1.2 | 1.1 | 0.9–1.4 |
| Hip fracture | 2.6 | 1.3–5.3 | 1.9 | 0.9–4.1 | 2.4 | 1.1–5.6 | 4.4 | 2.9–6.8 | 4.6 | 2.2–9.9 | 2.8 | 1.6–4.8 | 3.0 | 1.9–4.6 | 3.1 | 2.3–4.2 |

* Based on proportional hazards models, adjusted for age and presence of conditions at baseline.
† RR, relative risk; CI, confidence interval.

education were independently associated with mobility outcome in men. In women, only income was associated with the outcome after controlling for educational status and chronic conditions. The association of measures of socioeconomic status with a functional status outcome has been demonstrated in a number of other studies (4–8). In this study, the associations found for income and education remained significant even after controlling for a long list of important chronic conditions. This is analogous to previous research that found that known risk factors for coronary heart disease could not fully account for the association of socioeconomic status and cardiovascular mortality (22, 23). Part II of this study, by La Croix et al. (10), examines the relation of current health practices to maintenance of mobility, taking income and education into consideration. Our results highlight the need to understand much more fully factors such as lifelong health practices and access to medical care that may be responsible for poorer functional outcome in older persons with low income and education.

Five baseline cardiovascular conditions (heart attack, stroke, dyspnea, exertional leg pain, and high blood pressure) were associated with significantly increased risk of mobility loss. The report at baseline of having been diagnosed with a heart attack imparted a small (20–30 percent), yet significant, increase in the risk of losing mobility. In two other studies (5, 7), self-report of heart disease was not significantly associated with maintaining high levels of functioning, although in the study by Mor et al. (7) the relative risk for heart disease for losing high function was greater than in this study. The Framingham Heart Study (24) examined the association of specific manifestations of coronary heart disease and disability and found angina pectoris to be a stronger predictor of disability than was found in this study. The designs of the two studies differed, however, in that the Framingham Heart Study did not determine level of functioning at baseline or at any time during the follow-up period prior to the assessment done on survivors at the end of the study period.

Stroke, dyspnea, and exertional leg pain were the baseline conditions associated with the highest risk of mobility loss in this study. In case series, stroke has been demonstrated to have a large impact on functional status in a high proportion of survivors (25–27). In an analysis of data from the Longitudinal Study on Aging, baseline report of stroke was found to be significantly associated with loss of functioning in those with initially high functional status (7). Analyses of data from the Framingham Heart Study showed a significant association of stroke with disability in men and women, but showed that stroke explained a larger percentage of the variance in physical disability in men (28). Another analysis of Framingham data showed that, among a number of functional outcomes studied, the need for the help of another person with ambulation was nearly four times as common in those with stroke compared with a nonstroke control group (29). Dyspnea was not significantly associated with functional decline in the Alameda County Study, but it was assessed at baseline when the cohort was mostly middle aged and had a low prevalence of dyspnea (5). Exertional leg pain has not previously been identified in a population-based study as a risk factor for functional decline.

Hypertension was found to be a predictor of mobility loss in this study and a significant predictor of functional decline in several other studies (5–8). This association persisted even after the major manifestations of hypertension, which would be presumed to cause functional decline, heart attack, and stroke, were included in the model (table 3). Additional adjustment for new heart disease and stroke events that occurred during follow-up did not alter this association (results not shown). Further research is needed to explain the association of hypertension with functional decline. Possible explanations include the adverse effects of antihypertensive drug therapy and the interaction of hypertension or drugs used to treat it with other diseases.

Diabetes was found to be a significant predictor of mobility loss in this study and in that of Mor et al. (7) despite the fact that

its effect was adjusted for the presence of cardiovascular diseases for which it is an important risk factor. This would imply that other manifestations of diabetes, such as peripheral neuropathy and retinopathy, may play a role in its impact on functional decline. Further research, specifically focused on diabetics, would be useful in elucidating how the many manifestations of this disease cause disability in older persons.

No relation was found between arthritis and loss of mobility. The questions used to assess arthritis did not specify the involved joints, and positive responses were therefore given by those with any arthritis, including upper extremity arthritis. In analysis of data from the Longitudinal Study on Aging, in which arthritis as diagnosed by a physician was specifically queried, arthritis was both cross-sectionally (30) and prospectively (6, 7) associated with disability. It is likely that far more information than has been available in large epidemiologic studies will be needed to fully appreciate the association of joint disease and disability. For example, a study that focused on arthritis of the knee demonstrated that the magnitude of the association of arthritis and disability was dependent on specifically how the diagnosis was made (31).

No other study of functional outcomes has looked at new disease events occurring during the follow-up period. The evaluation of prevalent disease at baseline cannot distinguish whether functional decline is related to a new occurrence of the disease (which is more likely in someone who already has had one occurrence) or if it simply results from steady decline associated with the chronic disease state that was present at baseline. Our study showed that, among those diseases for which yearly information was available, there were differing relations of past and new disease with loss of mobility. For heart attack and stroke, both a history of the event and a new event were independently predictive of mobility loss, even after adjustment for both past occurrence and a new event in the same model (table 5). In both cases, the risk of mobility loss associated with a new event was substantially higher than that associated with baseline report of the condition. For diabetes, only past history, and not new diagnosis, was associated with mobility loss, while for hip fracture and cancer, only a new occurrence, and not a past history, was associated with mobility loss.

These results are very informative about the effects of these important diseases on disability. A history of heart disease and stroke put subjects at increased risk of functional decline, whether or not a new event occurred. Diabetes, in contrast, exerted a long-term effect on loss of mobility, but newly diagnosed diabetes was probably not present for long enough to exert an adverse effect over a 4-year follow-up period. For those with a history of hip fracture or cancer at baseline who had remained mobile or had regained mobility prior to baseline, their prior condition put them at no added risk of mobility loss, but those who suffered a new event, especially a hip fracture, carried a high risk of mobility loss.

Comorbidity has been shown previously in cross-sectional studies (30, 32) to be strongly associated with disability, but its effect in prospective epidemiologic studies has not been evaluated. This study demonstrated a clear increase in risk of mobility loss with an increasing number of chronic conditions, with the level of risk very similar for men and women. The importance of comorbidity in the older population, even in those who are highly functional, can be inferred from these findings. This study represented the burden of disease very simplistically by summing the number of conditions, without considering the specific conditions or severity of the conditions, yet even so, a strong association of comorbidity with functional decline was found.

The strengths of this study lie in its prospective design and its use of large populations that were free of mobility limitation at baseline and were followed for a period of time sufficient for a large number of events, defined as mobility loss, to occur. The high initial response rates, low rates of loss to follow-up, and consistency of results across the three communities and between men

and women support the generalizability of the findings.

Because the main objective of this study was to identify factors associated with maintaining mobility, the endpoint selected was the loss of mobility at any point during the follow-up. We did not investigate individuals who at one time point lost and then later regained mobility as a separate subgroup (17.8 percent of all those who lost mobility). However, our results were unchanged when this subgroup was excluded from analyses. Although not a focus of this study, identification of the factors associated with regaining function after an initial loss is an area that merits its own investigation.

The main limitation of the study is that data on baseline and newly occurring chronic conditions and mobility were self-reported. Although participants were asked whether a physician or other health care provider had told them of the presence of a disease, this was not independently confirmed. In the case of self-reported hip fracture, it has been demonstrated in the New Haven cohort that 94 percent of all self-reported hip fractures were verified by review of hospital records (20). These results and those of other studies (33) indicate that self-report is often an accurate indicator of disease status in older persons. However, a systematic bias, in which those who under- or overreported chronic conditions also similarly under- or overreported mobility limitation, would result in an overestimate of the associations found in this study. No measures of disease severity, which may be very important in explaining the role of disease in functional loss, were available in this study.

The modest or absent risk of functional decline in those with conditions at baseline raises the possibility that older adults who maintain or regain function in the face of major health events are likely to sustain mobility for a number of years. For example, although a new hip fracture was shown to lead to loss of function in this and other studies (34), our study showed that for those with a history of hip fracture who regained mobility, their hip fracture history did not put them at added risk of functional decline. For those with a previous heart attack who were mobile, there was only a small increase in risk of functional decline. In considering interventions to reduce long-term functional decline in those with potentially disabling conditions, it would be important to evaluate further whether the low risk of functional decline in those who have initially recovered function is simply related to the severity of underlying disease and of the initial event or whether rehabilitation to the point of little or no disability will lead to long-term maintenance of function.

Further work utilizing the mobility definition employed here would be valuable and practical, as the two questions defining mobility have been used in similar or identical form in other prospective aging studies. The mobility domain taps an area of higher functioning than the activities of daily living and is therefore more appropriate for community-based studies. Furthermore, it is more specific as to what it represents than the widely used scale of higher functioning, the instrumental activities of daily living, which assesses activities such as shopping and preparing meals. Because mobility evaluates the higher end of the functional spectrum, its study may provide a clearer picture of disease-disability associations than investigations of the severe end of the functional spectrum, in which long-standing chronic diseases and disability may be more difficult to sort out.

## REFERENCES

1. Schneider EL, Guralnik JM. The aging of America: impact on health care costs. JAMA 1990;263: 2335–40.
2. Branch LG. Health practices and incident disability among the elderly. Am J Public Health 1985;75: 1436–9.
3. Palmore EB, Nowlin JB, Wang HS. Predictors of function among the old-old: a 10-year follow-up. J Gerontol 1985;40:244–50.
4. Pinsky JL, Leaverton PE, Stokes J. Predictors of good function: the Framingham Study. J Chronic Dis 1987;40(Suppl 1):159S-67S.
5. Guralnik JM, Kaplan GA. Predictors of healthy aging: prospective evidence from the Alameda County Study. Am J Public Health 1989;79: 703–8.

6. Harris T, Kovar MG, Suzman R, et al. Longitudinal study of physical ability in the oldest-old. Am J Public Health 1989;79:698–702.
7. Mor V, Murphy J, Masterson-Allen S, et al. Risk of functional decline among well elders. J Clin Epidemiol 1989;42:895–904.
8. Keil JE, Gazes PC, Sutherland SE, et al. Predictors of physical disability in elderly blacks and whites in the Charleston Heart Study. J Clin Epidemiol 1989;42:521–9.
9. Roos N, Havens B. Predictors of successful aging: a twelve-year study of Manitoba elderly. Am J Public Health 1991;81:63–8.
10. LaCroix AZ, Guralnik JM, Berkman LF, et al. Maintaining mobility in late life. II. Smoking, alcohol consumption, physical activity, and body mass index. Am J Epidemiol 1993;137:858–69.
11. Cornoni-Huntley J, Brock DB, Ostfeld A, et al, eds. Established populations for epidemiologic studies of the elderly, resource data book. Bethesda, MD: National Institutes of Health, 1986. (NIH publication no. 86–2443).
12. Rosow I, Breslau N. A Guttman health scale for the aged. J Gerontol 1966;21:556–9.
13. LaCroix AZ, Guralnik JM, Curb JD, et al. Chest pain and coronary heart disease mortality among men and women in three communities. Circulation 1990;81:437–46.
14. Lane PW, Nelder JA. Analysis of covariance and standardization as instances of prediction. Biometrics 1982;38:613–21.
15. Cox DR. Regression models and life tables. J R Stat Soc (B) 1972;34:187–202.
16. Miller RG. Survival analysis. New York: John Wiley & Sons, 1981.
17. Harell FE. The PHGLM Procedure. In: SAS Institute, Inc. SUGI supplemental library user's guide. Version 5 ed. Cary, NC: SAS Institute, Inc., 1986:437–66.
18. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. N Engl J Med 1988;319:1701–7.
19. Nevitt MC, Cummings SR, Kidd S, et al. Risk factors for recurrent nonsyncopal falls: a prospective study. JAMA 1989;261:2663–8.
20. LaCroix AZ, Wienpahl J, White LR, et al. Thiazide diuretic agents and the incidence of hip fracture. N Engl J Med 1990;322:286–90.
21. Branch LG, Jette AM. A prospective study of long-term care institutionalization among the aged. Am J Public Health 1982;72:1373–9.
22. Rose G, Marmot MG. Social class and coronary heart disease. Br Heart J 1981;45:13–19.
23. Salonen JT. Socioeconomic status and risk of cancer, cerebral stroke, and death due to coronary heart disease and any disease: a longitudinal study in Eastern Finland. J Epidemiol Community Health 1982;36:294–7.
24. Pinsky JL, Jette AM, Branch LG, et al. The Framingham Disability Study: relationship of various coronary heart disease manifestations to disability in older persons living in the community. Am J Public Health 1990;80:1363–8.
25. Aho K, Harmsen P, Hatano S, et al. Cerebrovascular disease in the community: results of a WHO collaborative study. Bull World Health Organ 1980; 58:113–30.
26. Ahlsio B, Briton M, Murray V, et al. Disablement and quality of life after stroke. Stroke 1984;15: 886–90.
27. Kotila M, Waltimo O, Niemi ML, et al. The profile of recovery from stroke and factors influencing outcome. Stroke 1984;15:1039–44.
28. Jette AM, Pinsky JL, Branch LG, et al. The Framingham Disability Study: physical disability among community-dwelling survivors of stroke. J Clin Epidemiol 1988;41:719–26.
29. Gresham GE, Phillips TF, Wolf PA, et al. Epidemiologic profile of long-term stroke disability: the Framingham Study. Arch Phys Med Rehabil 1979; 60:487–91.
30. Verbrugge LM, Lepkowski JM, Imanaka Y. Comorbidity and its impact on disability. Milbank Q 1989;67:450–84.
31. Guccione AA, Felson DT, Anderson JJ. Defining arthritis and measuring functional status in elders: methodologic issues in the study of disease and physical disability. Am J Public Health 1990;80: 945–9.
32. Guralnik JM, LaCroix AZ, Everett DF, et al. Aging in the eighties: the prevalence of co-morbidity and its association with disability. Advance data from vital and health statistics. No. 170. Hyattsville, MD: National Center for Health Statistics, 1989.
33. Bush TL, Miller SR, Golden AL, et al. Self-report and medical record report agreement of selected medical conditions in the elderly. Am J Public Health 1989;79:1554–6.
34. Magaziner J, Simonsick EM, Kashner TM, et al. Predictors of functional recovery one year following hospital discharge for hip fracture: a prospective study. J Gerontol Med Sci 1990;45:M101–7.