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DISABILITY AS A PUBLIC HEALTH OUTCOME IN THE AGING POPULATION[1]

Jack M. Guralnik[1], Linda P. Fried[2], and Marcel E. Salive[1]
[1]Epidemiology, Demography, and Biometry Program, National Institute on Aging, Bethesda, Maryland 20892; [2]Departments of Medicine and Epidemiology, The Johns Hopkins Medical Institutions, Baltimore, Maryland 21205

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ABSTRACT

Improvements in life expectancy in the twentieth century have resulted from major declines in mortality at younger ages, but it is less well recognized that mortality declines at older ages have also played a substantial role in prolonging expectation of life. A person reaching age 65 in 1900 could expect to live an additional 11.9 years. Life expectancy at age 65 rose to 14.4 years by 1960 and then increased by about three years in the next three decades, reaching 17.5 years in 1992 (56, 70). As a greater proportion of the population survives to very old ages, the public health impact of the burden of disease and disability and related utilization of medical care and need for supportive and long-term care has become an important concern. In particular, the ability of the older person to function independently in the community is a critically important public health issue. A growing body of research in the last decade has addressed the measurement of disability, factors related to its onset, consequences of disability, and the potential for preventive interventions. This article summarizes the state of the art in these areas and discusses their public health relevance.

ASSESSING FUNCTIONING IN OLDER POPULATIONS

A wide range of instruments has been developed for assessing physical functioning and disability in older persons. The assessment of disability was first used to identify functional impairments in persons with serious chronic

diseases such as cancer (53) and stroke (55), particularly in institutional settings. In the past two decades these measures have been increasingly used to characterize older persons in various settings and for many purposes, including clinical assessment, clinical research, and community-based epidemiological studies. Disability is generally assessed through self-report or proxy report of difficulty or need for help in basic self-care tasks, more complex tasks necessary for living independently in the community, and tasks related to mobility and other more basic movements of the body. Additionally, physical performance measures, which objectively assess various aspects of physical functioning, have been used recently to supplement self-report of disability.

Basic self-care activities such as bathing, dressing, transferring from a bed to a chair, using the toilet, and eating are commonly referred to as activities of daily living (ADLs) (55) and are the most frequently used indicators of physical disability. These measures reflect a substantial degree of disability, and, in general, the more ADLs with which a person has difficulty, the more severe his or her disability. The prevalence of difficulty or need for help in performing ADLs is lower than other measures of disability, and ADLs work well to identify the most severely disabled individuals.

Disability has also been measured in relation to the ability to perform instrumental activities of daily living (IADLs), tasks considered necessary for independent living in the community. These tasks are generally considered to be more difficult and complex than those in the self-care domain and include activities such as shopping, preparing food, housekeeping, doing laundry, using transportation, taking medications, handling money, and using the telephone (64).

In addition to ADLs and IADLs, a wide variety of other measures of self-reported functional status have been developed (1, 9, 52). The assessment of mobility is an especially important part of functional evaluations. Mobility can be evaluated by self-report using a hierarchical approach, starting with simple mobility tasks such as transferring from a bed to a chair and progressing through walking short and longer distances, and climbing stairs. Surveys can also be used to assess more basic functions related to range of motion, strength and endurance (69), as well as the higher end of the functional spectrum, including vigorous exercise and walking medium and long distances (73).

A number of survey batteries that assess multiple domains of functional status have been developed, some specific to functioning and others designed to measure overall health status. For example, the Functional Status Questionnaire assesses physical function, psychological function, and social-role function (48). The Sickness Impact Profile, a general health status evaluation instrument, contains a large proportion of items that assess aspects of physical functioning and disability, including domains of mobility and confinement,

movement of the body, personal hygiene, ambulation, usual daily work, and household management (4).

THE PREVALENCE OF DISABILITY IN THE OLDER POPULATION

Traditionally, public health officials evaluate the status of a population using total and cause-specific mortality rates and disease incidence and prevalence rates. Measures of disability add an important perspective on the health status of older populations. Although the presence of disease is certainly important, the functional consequences of disease in older people have major implications for quality of life, need for supportive services, and ultimately, need for long-term care, whether at home or in an institution. Disability status may reflect severity of disease, and measuring disability offers an important approach to summarizing the overall impact of multiple co-existing chronic conditions.

The largest national prevalence survey of disability was administered to more than 41 million persons as part of the 1990 United States Census long form (62). A two-part question asked first about difficulty in going outside alone (mobility disability) and second about taking care of personal needs such as bathing, dressing, or getting around in the home (ADL disability). Overall, an estimated 13.2 million Americans (70.5 per 1000 persons) age 16 years and older had a mobility or ADL disability, about half of whom were 65 years and older. Among those age 65 years and older, 16% had difficulty with mobility-related activities and 12% had difficulty with ADLs. A number of large national surveys in the 1980s specifically assessed disability in the older population (94). In analyses that evaluated ADL disability rates for a set of items common to all these surveys (bathing, dressing, eating, transferring, and toileting), it was found that the prevalence of *receiving help* with one or more of these ADLs ranged from 5.0 to 8.1% of noninstitutionalized adults age 65 years and older (94).

Both national and local surveys of representative older populations show consistent associations of disability with demographic characteristics. Prevalence of disability increases substantially with increasing age, is more common in women than men in age groups above age 75 years, is higher in those with lower education and income levels, and is somewhat higher in ethnic minorities (12, 13, 31). In longitudinal studies, men and women have similar incidence rates of disability, but women survive longer after becoming disabled, which accounts for the higher prevalence of disability in older women (85).

Surveys of disability in the older community-based population do not capture its full magnitude because a substantial proportion of the disabled population resides in nursing homes. Of nursing home residents age 65 years and

older, over 90% are dependent in one or more ADLs and two thirds are reported to have memory impairment or disorientation (46). In 1987, an estimated 6.8% of persons ages 65 years and older used a nursing home at some time during the year, including 8.2% of women and 4.7% of men (21). Use of nursing homes increases dramatically with increasing age. Less than 1.5% of persons ages 65 to 69 used a nursing home in 1987. In the age group 85 to 89 years, one fourth of women and one fifth of men used a nursing home, and among those age 90 years and older, 46% of women and 31% of men used a nursing home in 1987. With the use of data from both the National Health Interview Survey and the National Nursing Home Survey, estimates of the impact of disability in the total older population have been made, including those dwelling in both the community and nursing homes (45, 80). Overall, 15% of men and 22% of women either live at home and need the help of another person with ADLs or IADLs or are resident in a nursing home (80). About 10% of men and women ages 65 to 74 years are dependent at home or live in a nursing home, but this figure rises to 46% of men and 62% of women in the 85 and older age group.

Measuring disability prevalence in a single population over time and making comparisons between populations would be important for understanding trends or differences in the public health impact of poor health in older persons. However, assessments have not always been standardized to the point where these comparisons can be readily made. Different surveys may assess the same disability items but may ask questions in a slightly different manner, translations of questionnaires may yield slightly different questions, and cultural differences in the way questions are interpreted and answered may also lead to different responses.

The U.S. National Long-Term Care Survey has been administered in an identical manner at three times in the 1980s (66). Analyses of these data have shown a modest decline in the prevalence of disability in ADLs and IADLs, although this decline was not uniform across all strata of disability. An effort has been made to develop instruments that can lead to useful comparisons of disability across countries, but this work is still in its early stages (20). In comparing local community disability rates even when the same instrument is administered, caution must be used in interpreting the data because out-migration of disabled individuals may occur from different communities at different rates. This was demonstrated in the communities of the Established Populations for the Epidemiologic Study of the Elderly (EPESE) (13). Prevalence of disability in the East Boston site was substantially higher than for the two rural counties in Iowa. However, this prevalence was related in part to greater use of home health care in East Boston (10), allowing individuals to remain in the community, whereas in Iowa persons were much more likely to leave the community and enter nursing homes (23). Thus, cross-sectional data revealed

a greater proportion of disabled individuals in the East Boston community, but longitudinal follow-up revealed that older persons in East Boston may not have been in poorer health but were simply more likely to remain in the community when they became disabled.

SOCIAL AND HEALTH CONSEQUENCES OF DISABILITY

Disability in older persons affects both their quality of life and need for care, and has a major impact on their families and the entire health care system. Physical disability is associated with restrictions that affect all aspects of daily life. For example, in the Women's Health and Aging Study, a community-based study that recruited the one third most disabled women living in the community, it was found that in a typical week 34% of these disabled women did not go beyond their neighborhood, including 15% who didn't leave their homes, and that 12% stopped using rooms in their homes because of their disabilities (38).

The burden of care related to disability in the older population goes well beyond that received in nursing homes. Figure 1 combines data from the National Nursing Home Survey and the Supplement on Aging of the National Health Interview Survey to depict the type of care received according to disability level. A majority of persons with disability in IADLs receive only

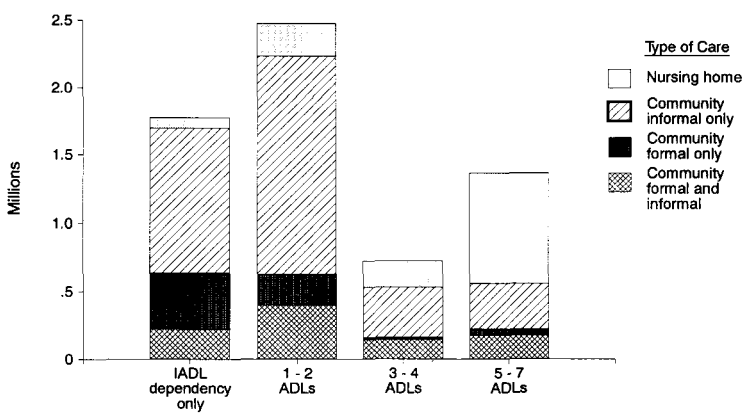

Figure 1 Number of persons who receive nursing home care and informal and formal care in the community according to level of disability. Community-dwelling persons represented in this figure reported actually receiving help for one or more activities of daily living (ADLs) or instrumental activities of daily living (IADLs). ADLs include bathing, dressing, eating, transferring, walking, using the toilet, and continence. IADLs include preparing meals, shopping, managing money, doing light housework, doing heavy housework, and getting outside. Source: Reference 45.

informal care (unpaid care provided by family, friends, and neighbors), with very few residing in nursing homes. The institutionalized proportion rises with the severity of disability, reaching 59% in persons with dependency in 5 to 7 ADLs, an indicator of severe disability. However, even at this high level of disability, more than one third of persons live at home and receive a combination of formal and informal care. Figure 1 clearly illustrates the importance of informal care in meeting the daily needs of older persons with lesser degrees of disability. Although those with disability in IADLs often meet their needs with formal care alone, few persons with one or two ADLs and almost no one with three or more ADLs reside in the community using only formal care.

Living arrangements of older persons in the community who develop disability play an important role in determining the source of their care and their eventual ability to remain in the community. The most likely source of informal care is, first, the spouse, if living and capable, followed by children and others. The magnitude of the reliance of older disabled people on informal care, illustrated in Figure 1, is of major public health concern for the future as the older population expands and the availability of informal care resources, especially from children, contracts.

Longitudinal epidemiologic studies have demonstrated that disability in older persons is a predictor of numerous important outcomes. In fact, in most prospective analyses in aging cohorts, disability is the strongest predictor of adverse outcomes after age. Because disability is an excellent marker for the overall burden and severity of disease in the older person, it is a strong predictor of future mortality. This has been found in both community-dwelling populations (6, 14, 58, 93) as well as in institutions, where those who are severely disabled are more likely to die than those with less disability (15). In the disabled community-dwelling population, there is also a strong mortality gradient according to the degree of disability. Two-year follow-up data from the National Long-Term Care Survey showed mortality rates rising from 15.2% in those with IADL disability only to 20.7% in those with disability in one or two ADLs, 24% in those with three or four ADLs, and 37.2% in those with five or six ADLs (65). In the EPESE communities, four-year all-cause mortality rates were four to six times higher in those age 70 years and older with ADL disability compared with persons who were nondisabled. Additionally, those with mobility disability, defined as the need for help in climbing stairs and/or walking 1/2 mile, were 2.5 times as likely to die as those with no disability (14). Even after adjusting for demographic characteristics, behavioral risk factors such as smoking and weight status, and several chronic diseases, disability continues to be an important predictor of mortality.

Disability status is a strong predictor of other health outcomes, including further declines in functioning (8, 65), increased number of acute illnesses, and increased risk of falls and injuries (9, 26). Performance on objective

measures of functioning is highly predictive of falls both within an institution (88) and in the community (71, 87). Disability is also a predictor of health care utilization, including increased risk for recurrent hospitalization, greater use of outpatient care (26), and institutionalization (7, 23, 33, 79). Mor and colleagues (68) have also shown that functional status and change in function over time are associated with increased hospital use and cost of care. Other researchers have demonstrated a clear relationship between disability level and use of physician services (92) and paid home care (84).

Contrary to the belief that disability progresses in an inexorable downhill course, multiple longitudinal studies have demonstrated that it is not rare for individuals to report less disability in follow-up evaluations than they have reported at baseline. In the Alameda County Study, for example, 13% of men and 20% of women improved in functioning over a six-year period (85). In the National Long-Term Care Survey, 18% of older adults with one or two ADL disabilities did not report disability two years later (65). The probability of recovery decreased, however, with increasing disability at baseline. In those with three or more ADL disabilities, less than 6% reported no ADL disability two years later. The likelihood of improvement also decreases with longer duration of disability (8).

DISEASE AND DISABILITY

Compared to the extensive research devoted to understanding the pathophysiology and risk factors for specific diseases, relatively little work has examined the risk factors for functional decrements in aging. Most disability in older adults is caused by chronic conditions, injuries, and disuse. A theoretical framework for the pathway from disease to disability, which includes intermediate steps such as impairment and functional limitation, has been proposed by the World Health Organization (98) and the Institute of Medicine (47). In recent years, a number of epidemiologic and clinical investigations have explored the relationship of disease and disability in the older population and increased our understanding of the impact of specific diseases and the effect of co-occurrence of multiple chronic conditions on disability. However, the intricacies of the pathway from disease to disability, the mechanisms whereby specific diseases cause disability, and the manner in which multiple diseases interact to cause disability all need further study.

In evaluating a patient presenting with a new stroke or hip fracture, the physician may clearly understand the cause of the patient's disability. However, changing the perspective and trying to understand why an individual presenting with disability who has multiple chronic conditions has reached his or her level of functioning is often not so simple. Going a step further and attempting to understand the diseases responsible for disability from a popu-

lation perspective is a particular challenge. In addition to the difficulty in understanding the interaction of multiple co-occurring conditions, unraveling the pathway from disease to disability is difficult because disability may represent decline in several different aspects of functioning, each of which may be affected by a different disease (27). The pathway from disease to disability can be influenced by many nondisease factors such as depression and social support. In addition, disability itself may lead to further disability or to new chronic medical conditions, which can then cause more disability.

Population-based studies of older populations have been used to demonstrate both the cross-sectional and longitudinal association of specific chronic diseases with disability. This has been done for a nationally representative sample using the Longitudinal Study of Aging (5, 44, 67) and for major cohort studies such as the Framingham Heart Study (35, 49, 72), the Study of Osteoporotic Fractures (17), the Cardiovascular Health Study (19, 27), and the Alameda County Study (39, 85). A number of chronic conditions of aging have consistently been found to be strongly related to disability. These include heart disease (especially myocardial infarction, angina, and congestive heart failure), osteoarthritis (especially arthritis of the knees), hip fracture, diabetes, intermittent claudication, stroke, chronic obstructive pulmonary disease, visual impairment, hearing impairment, depression, and cognitive impairment.

Several studies have attempted to improve our understanding of the relative impact of specific diseases on population disability. In an important early study (24), Ford and colleagues estimated that arthritis was responsible for 34% of physical disability in the older population. Stroke, visual impairment, heart disease, and dementia taken together accounted for half of disability, with the final 15% accounted for by peripheral vascular disease, lung disease, depression, diabetes, hearing impairment, and hypertension. Kosorok and colleagues (57) estimated the number of days of restricted activity attributed to specific diseases and conditions using data from the National Health Interview Survey. This population of community-dwelling older adults reported an average of 31 restricted activity days per person per year. Of these, 18% were associated with falls, 14% with heart disease, 12% with arthritis, and smaller percentages with atherosclerosis, diabetes, malignancies, and osteoporosis.

Using data from over 5000 participants in the Cardiovascular Health Study, Ettinger and colleagues (19) described disabilities reported by this population and the diseases that participants stated were the causes of specific disabilities in up to 17 tasks. Arthritis was the most commonly reported cause of disability, followed by heart disease, injury, old age, lung disease, and stroke. Arthritis was reported to be the cause of difficulty in a wide range of specific tasks, in contrast to other conditions that appear to have a more specific relationship with certain disabilities. For example, heart disease was reported to be asso-

ciated with difficulty in activities requiring endurance, and stroke with upper extremity and self-care tasks. The validity of self-report of the disease responsible for disability is not known at this time, but the kind of information attainable from such a study may be useful from a public health as well as clinical point of view. If we can ascertain in a valid manner the specific underlying causes of disability in older people who may have multiple conditions, much interesting new research may be done in this field. Studies of the natural history of disability would be enhanced by being able to take into account the primary diseases underlying an individual's disabilities, and our understanding of potentially modifiable risk factors that affect the progression of disability could be considerably refined by knowing how these factors affect specific disease-disability combinations.

Another valuable innovation in this area is the estimation of population attributable risk of disability. This approach is analogous to estimating population attributable risk of disease as a reflection of the impact of specific risk factors. The estimation of the population attributable risk of specific diseases for disability is related to both the strength of the association between those diseases and disability, and the prevalence of the specific diseases. Guccione and colleagues (35) used the Framingham Heart Study cohort to examine the relationship of physician-diagnosed medical conditions and seven functional activities related to IADLs and mobility. The disease-disability relationship was examined after adjusting for age, sex, and comorbidity. Stroke was associated with disability in all seven tasks; hip fracture and depression were associated with disability in five tasks; and other conditions, including knee osteoarthritis, heart disease, congestive heart failure, and chronic obstructive pulmonary disease, were each associated with disability in four tasks. Population attributable risks were presented separately for each of the seven tasks. For example, attributable risk of specific diseases for difficulty in walking a mile was as follows: knee osteoarthritis, 15%; depression, 10%; stroke, 9%; heart disease, 9%; intermittent claudication, 7%; hip fracture, 5%; chronic obstructive pulmonary disease, 5%; diabetes, 4%; and congestive heart failure, 2%.

Although from a public health perspective it would be desirable to understand the impact of specific diseases on *overall* disability status, there is evidence that a great deal of information can be lost in aggregating a variety of heterogenous measures of disability into a single disability outcome measure. Using a subset of the Framingham cohort that received knee radiographs, Guccione (34) showed only a modest association between osteoarthritis and a summary measure of functional status. As expected, stronger relationships were seen between osteoarthritis of the knee and specific tasks that included stair climbing, walking a mile, and housekeeping. This study also concluded that a generic classification of arthritis was less useful in identifying strong

disease-disability relationships than a more refined definition that was limited to a specific joint and included classification information on both symptoms and radiographic grade. Similar types of specific relationships were also found in the study by Ettinger and colleagues (19).

The co-occurrence of multiple chronic conditions, or comorbidity, is common in the older population. In a nationally representative sample of persons who were asked about physician-diagnosed chronic conditions, nearly half of those aged 60 years and older reported two or more chronic conditions out of a list of the nine most commonly reported chronic conditions. In general, the prevalence of comorbidity for specific combinations of conditions was strongly related to the prevalence of each condition itself. For example, the two most commonly reported chronic conditions, high blood pressure and arthritis, co-occurred in 24% of this older population (41). Multiple impairments have also been found to co-occur in persons with disability. In community-dwelling disabled persons who received a clinical evaluation, over half had impairments in more than one physiological system, including cognitive, sensory, neurological, musculoskeletal, and cardiorespiratory (11).

The association of comorbidity with disability has been clearly demonstrated. Cross-sectional studies have demonstrated that with an increasing number of chronic diseases there is a stepwise increase in disability in ADLs (41), IADLs (25), and mobility (89). A prospective analysis of data from the EPESE study evaluated the impact of comorbidity in persons who, at the study baseline, reported being mobile, defined as the ability to walk 1/2 mile and climb stairs without help. Among these initially nondisabled individuals, those with two conditions were more than 1.5 times as likely to develop mobility disability compared to those with no chronic conditions, those with three conditions were 2.5 times more likely to become disabled, and those with four or more conditions were nearly 3 times as likely to become disabled during the four-year follow-up period (40). In a study that evaluated the impact of four specific chronic conditions (cerebrovascular disease, arthritis, coronary artery disease, and diabetes) on ADL and IADL disability and death, it was found that those with none of these conditions had a 3% chance of becoming disabled and a 4% chance of dying over the four-year follow-up period, compared to those with all four conditions, who had a 13% chance of becoming disabled and a 23% chance of dying (5).

Although the relationship between the number of chronic diseases and disability occurrence is quite striking, further progress in this field will require the study of specific combinations of diseases and their effect on disability. Arthritis has been studied in relation to other diseases in causing disability. In one study, arthritis was found to cause substantially greater risk of mobility difficulty when it was associated with other comorbid conditions than when it was found alone (90). More specific interactions between arthritis and other

diseases were evaluated by Ettinger and colleagues using data from the National Health and Nutrition Epidemiologic Follow-up Study (18). In comparison with subjects with no knee osteoarthritis or heart disease, the relative risk for onset of difficulty with ambulation was over 4 for those with knee osteoarthritis alone, 2.3 for people with heart disease alone, but 13.6 for subjects with both knee osteoarthritis and heart disease. In contrast, the synergistic effect was not seen for the combination of knee osteoarthritis and hypertension. Those with hypertension alone had a relative risk of 1.3 compared to those without hypertension or osteoarthritis, and those with knee osteoarthritis plus hypertension had a relative risk of 2.5. From the standpoint of prevention of disability, targeting particular diseases that act synergistically with other diseases in causing disability could be very important in reducing overall population risk of disability.

In addition to disease status, a number of demographic characteristics and behavioral risk factors have also been found to be predictors of disability onset (5). Many of these factors are strongly related to disease status, but they have also been found to be independent predictors of disability onset after adjustment for the presence of specific diseases. For example, in the study from the EPESE populations discussed above (40), incident loss of mobility was 1.5 times as common in those in the lowest versus the highest income bracket, after adjustment for a long list of chronic conditions. Additionally, after adjusting for these chronic conditions and income, men were at a significantly increased risk of disability if they had less than a high school education, although this increased risk was not present in women.

Behavioral risk factors consistently associated with disability onset include smoking, lack of exercise, and excess weight. In the EPESE study on mobility loss, among persons who were not disabled at baseline those who currently smoked were at significantly increased risk of losing mobility over the four-year follow-up period, even after adjusting for the presence of chronic conditions (61). In men, former smokers were at no greater risk of mobility loss than nonsmokers, suggesting that smoking cessation may have benefits that go beyond disease prevention to the prevention of functional decline. Lack of exercise has been demonstrated to place individuals at increased risk of disability, whereas decreased risk has been shown in those who are physically active (61, 83). The risk of mobility loss in individuals who are overweight has been clearly demonstrated (61, 63). Furthermore, Launer and colleagues (63) demonstrated that change in weight status was a strong predictor of loss of mobility. Persons who had been in the highest tertile of body mass index (BMI) in the past who then lost weight were eight times as likely to develop disability compared to those with stable low BMI. This was a substantially greater risk than for those with high BMI who remained stable or gained weight. In those who were in the middle tertile of BMI in

the past, significantly increased risks for disability were found for those who both gained weight and lost weight, but not for those who remained stable. Finally, in persons in the lowest tertile of past BMI, those who gained weight were not at increased risk, but those who lost weight were three times as likely to develop disability.

PHYSICAL PERFORMANCE MEASURES

A recent innovation in assessing functional status in older persons has been the development of physical performance measures. These are assessment instruments that objectively evaluate a specific aspect of physical functioning by having the individual perform a standardized task that is evaluated using objective, predetermined criteria (36). In many of these tasks the level of performance is evaluated by timing the task, whereas in others the evaluation is simply of the subject's ability to complete the task.

The assessment of disability in older persons has traditionally relied on self-report or proxy report, and the use of objective physical performance measures is appealing because it allows for direct, standardized assessment. This approach is analogous to assessment methods in other domains of functional status. For example, in the domains of cognitive functioning, hearing, and vision, comprehensive evaluation includes both self- or proxy report of functional difficulties and standardized testing to objectively document functional decrements, such as the use of a mental status questionnaire, visual acuity testing, and audiometry.

A growing body of research has demonstrated that physical performance measures add important information in the assessment of older persons. Performance measures identify functional problems that were not reported by the individual or family (16, 78). They have been demonstrated to be strong predictors of outcomes such as mortality (43, 75), falls (71, 76, 87), institutionalization (43, 75, 95), and other health services utilization (60, 95). Specific performance measures have been demonstrated to show improvement in response to interventions such as exercise (22) and cataract surgery (2), and to decline after hospitalization and with the onset of new health problems (82). Evidence has also been developed that performance measures can validly define a gradient of functioning even at the upper end of the functional spectrum (42, 43, 37, 82), and are therefore able to assess the full range of functional status better than self-report measures, which mainly identify the presence of overt disability.

Batteries of physical performance measures, which combine a group of related tasks, have been developed for a variety of purposes. An early performance battery, the Performance Activities of Daily Living, assesses 16 activities such as drinking from a cup, combing the hair, and turning a key

in a lock. This battery was designed to assess moderately to severely disabled older persons (59). A more recent, comprehensive battery developed for very frail or nursing home patients assesses range of motion, strength, balance, and mobility (32). A battery of timed manual performance tasks has been extensively evaluated and utilized in comprehensive geriatric assessment settings (81, 95, 96). Lower extremity functioning was evaluated in the EPESE study in participants' homes, using a short battery that assessed balance and the times for participants to rise from a chair five times and walk eight feet (43). Lower extremity functioning is also the focus of the Physical Performance Mobility Examination, a comprehensive evaluation of transfer mobility and lower extremity function developed for use in hospitalized patients (97). Performance measures developed specifically to assess gait and balance (3, 88) have been extensively used. The Physical Performance Test (74) is a battery that assesses multiple categories of physical functioning, such as writing a sentence, simulated eating, putting on a jacket, walking 50 feet, and climbing stairs.

Methodologic work that has evaluated physical performance measures has shown them to have excellent reliability and validity. Test-retest and interobserver reliability, internal consistency reliability for summary scales, and a variety of assessments of validity, including predictive validity for important and relevant outcomes, have been demonstrated for many of these measures. Investigations continue into the use of these measures to evaluate change over time.

Despite the excellent psychometric properties of physical performance measures, a number of issues related to actual application remain to be resolved. Self-reported disability has stood the test of time as an important evaluation tool for the older population, both because of ease of administration and face validity, and it remains an open question as to the circumstances in which objective physical performance measures add useful information to a research study or clinical evaluation. Use of these measures certainly adds cost in terms of training of assessors, maintenance of quality control, and imposing of burden on participants.

A further issue to be clarified is the potential role of physical performance measures outside the research setting. Although these measures have already been employed in comprehensive geriatric assessment protocols and for evaluation of eligibility for support services and long-term care, formal studies have not yet demonstrated that physical performance measures provide useful additional information beyond that currently obtained by self-report. In the clinical setting, these measures may work well to establish the link between specific diseases and specific disabilities, whereas in persons with little or no disability, they may serve as indicators of early functional decline when used to screen patients over a period of time.

IDENTIFYING A PRECLINICAL STATE OF DISABILITY

It has been hypothesized that there is a "preclinical" state of functional loss, in which the individual perceives and reports no difficulties in traditional activities such as ADLs and IADLs, but has functional decrements that can be otherwise documented (29). In these cases, individuals may have impairments or physiological decrements that affect their functional level, but they can compensate in ways that maintain their ability to function in daily life. This compensation may include doing an activity less often or changing the method of performing it, and the individual may not report any difficulty when gradually making these kinds of changes over time. In the Women's Health and Aging Study, among women who reported no difficulty in walking up ten steps without resting, 37% said they did this task less often and 46% said they did it differently from how they did it in the past. As expected, nearly all individuals who reported difficulty in doing this task also said they did it less often or differently. Among those women reporting no difficulty with shopping for personal items, 22% said that they did it differently, compared to women who reported difficulty shopping, of whom over 80% reported that they did this task differently than they did in the past (38).

Performance measures of functioning have proven particularly useful in identifying a hierarchy of functioning in the nondisabled older population. Data from the MacArthur Study of Successful Aging demonstrated, in a population of high-functioning older adults, that performance measures were related to other measures of health status (42) and that lower performance at baseline was predictive of further decline in performance (82). Prospective data from the EPESE study also support the validity of performance measures in assessing functional status at the healthy end of the spectrum. In the total population, a gradient of risk for both mortality and nursing home admission was seen across the full spectrum of physical performance, including nondisabled individuals at the high end of the range of performance (43). In further analyses restricted to individuals who reported no disability in ADLs or items assessing mobility, it was demonstrated that performance, in terms of gait velocity, balance, and ability to rise from a chair, was highly predictive of the subsequent onset, one and four years later, of both ADL disability and disability in mobility (37). Nondisabled individuals who had lower scores on these performance tests were four to five times more likely to have disability four years later than those with the best scores. The performance measures therefore identify a subset of nondisabled individuals who may be thought of as having preclinical disability because they are at high risk of progressing to frank disability over the next several years. The ability to identify nondisabled persons who are at increased risk of disability may prove valuable in targeting preventive interventions to a group that is vulnerable but may have a great deal of capacity to respond to these interventions.

COMPRESSION OF MORBIDITY AND THE MEASUREMENT OF ACTIVE LIFE EXPECTANCY

An important public health issue is the relationship between length of life and the amount of time spent in the disabled state. Life expectancy has increased very substantially in this century. One consequence that has recently been recognized, however, is that escaping death during the early years from infectious diseases and other causes may mean that many more people survive to ages where they suffer from chronic diseases, which can lead to long-term disability and loss of independence. An important goal for the future is to increase longevity without increasing the number of years spent in the disabled or dependent state. Although the recent increase in longevity is well documented, it is not now clear whether these added years of life have been accompanied by years of health and vigor or of disease and disability. This question is of particular concern in the coming century, when continued life expectancy increases and unprecedented numbers of old and very old persons are projected. The theory of compression of morbidity predicts a future decrease in the number of years with severe disease and disability (30).

An important outcome measure that integrates disability onset with vital statistics data has been termed active life expectancy or disability-free life expectancy (54). Active life expectancy, which can be used to evaluate compression of morbidity, is defined as the average number of years an individual at a given age will survive and remain in the active, or nondisabled state. Most analyses of active life expectancy have employed the ADLs to define disability, with active life expectancy calculated using life table techniques that consider transitions from the active, nondisabled state to both death and disability. The original analysis of active life expectancy considered the transitions to both death and disability as irreversible (54). Since recent longitudinal studies have revealed that some disabled older persons make the transition back to the nondisabled state, alternate methods to calculate active life expectancy that incorporate these kinds of changes, using multistate life tables, have been developed (77).

The relationship over time between life expectancy and active life expectancy can be used to evaluate compression of morbidity. Three possible scenarios for population morbidity in women are illustrated schematically in Figure 2. The total length of the bars in this figure represents average life expectancy for women in 1990 and as projected by the Census Bureau for 2040. The length of the unshaded segments of the bars represents active or disability-free life expectancy, and the shaded areas of the bars represent average number of years in the disabled state. In scenario 1, the onset of disability has been postponed the same number of years as life expectancy has increased, and the number of years spent in the disabled state is unchanged

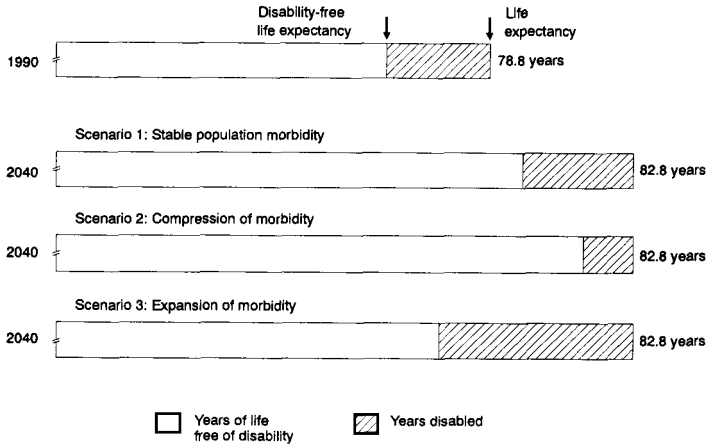

Figure 2 Scenarios for change in average burden of population disability level from 1990 to 2040. Compression of morbidity and alternatives.

from 1990. In scenario 2, there has been a compression of morbidity. Finally, in scenario 3, although disability-free life expectancy in 2040 has increased compared to 1990, it has not kept pace with increases in life expectancy and there is an expansion of population morbidity.

A vigorous debate over the prospects for a compression of morbidity began with a landmark paper by Fries in which he claimed that the compression of morbidity was inevitable in the coming years (30). He argued that in all species the maximum life span is fixed, that human beings are quickly approaching this limit, and that with a stable life expectancy any postponement of disability would result in a compression of morbidity. Although this logic is correct, others have pointed out that life expectancy is probably not going to reach its maximum level for at least the next half century, and we must consider that any of the alternate scenarios depicted in Figure 2 are possible in the face of increasing life expectancy.

PREVENTION OF DISABILITY IN THE OLDER POPULATION

With the rapid growth of the older population expected in the next century, the prevention or postponement of disability is of major public health importance. Prevention is appropriate at all three levels, primary, secondary, and tertiary. Ultimately, the best way to prevent disability from a disease is to prevent the disease itself. However, it is unrealistic to think that all major

chronic conditions of aging will be completely prevented in the old and very old population. Tertiary prevention, the prevention of adverse outcomes of disease, is particularly relevant in those with longstanding chronic diseases and comorbidity. Interventions range from the use of medical care for existing diseases through a variety of other strategies, including behavioral changes such as exercise and technological interventions to help the individual compensate for existing impairments. Ongoing observational studies that shed new light on factors important in the pathway from disease to disability will help in the development of potential intervention strategies that can be evaluated in randomized controlled trials.

In addition to interventions that treat a single disease or the functional consequences of a single disease, a new approach uses broad-based interventions oriented to impairments or functional declines that may be the result of multiple diseases, disuse, or the aging process itself. These interventions are applied in areas such as muscular weakness, poor balance, and low exercise tolerance. For example, resistance training has been shown to significantly improve strength in very old, frail, nursing home residents (22) and in community-dwelling ambulatory older persons (50, 51). Exercise regimens and behavioral interventions have also been demonstrated to improve postural stability (86).

As described above, an observational study using performance measures in the EPESE population demonstrated that intermediate endpoints, including balance and gait speed, are highly predictive of onset of disability in initially nondisabled individuals (37). There is thus evidence that interventions can affect intermediate endpoints and these intermediate endpoints are associated with the subsequent onset of disability. What remains to be studied is whether the kinds of interventions that improve aspects of functioning such as gait, strength, and balance can ultimately prevent or delay the onset of disability and other more distal outcomes.

Some success has been demonstrated in community intervention projects in preventing disability and falls. These projects have used multiple interventions targeted to specific problems identified in a medical and functional screening assessment. In a study based in a health maintenance organization, a nurse performed a home-based screening to identify problems that could be targeted with interventions for improving inadequate exercise, excessive alcohol use, increased fall risk, high-risk medication use, and vision and hearing impairments (91). Those receiving one or more of these interventions had a lower incidence of decline in functional status than controls after one year, although this difference had disappeared by the end of the second year. However, interventions in this trial were neither ongoing nor long-term, and greater effects might be seen with more intensive interventions. Another intervention that studied men and women 70 years of age and older who had one or more

risk factors for falls found that multiple interventions aimed at an individual's specific risk factors significantly reduced the rate of falls (86). These studies, in which multiple, potentially modifiable risk factors are assessed and targeted with specific interventions, may serve as models for future interventions.

As the size of the older population grows and life expectancy continues to increase, treatment and prevention strategies that address the functional consequences of disease and the burden of disability in a population living to older and older ages will become increasingly important. As demonstrated in this review, we are gaining increased appreciation for the methods that can lead to an understanding of the impact of disability in the population, risk factors along the pathway from disease to disability, and the consequences of disability. Ultimately, the goal of this effort must be to reduce the overall prevalence of disability in the population and increase the number of years in which older people lead highly functional, independent lives.

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