

Epidemiology of Aging

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EMERGENCE OF THE EPIDEMIOLOGY OF AGING

The last quarter of the 20th century has seen the formal coming of age of the study of the health, diseases, and disabilities of older adults, as well as of aging itself. Epidemiologic research on aging developed out of groundbreaking gerontologic studies that have been carried out since the 1940s, the establishment of the National Institute on Aging in 1974 (an outgrowth itself of the first White House Conference on Aging in 1961), and the maturation of programs in gerontology and geriatrics. The 1980s brought recognition that the US population was aging and the initiation of the first cohort studies that assessed older adults longitudinally, including a report by Branch et al. (1) showing that older adults could and would participate in epidemiologic cohort studies. Following this, the National Center for Health Statistics raised the age of the population studied in the Health Interview Survey to 75 years (2), and the National Institute on Aging funded the EPESE studies [Established Populations for the Epidemiologic Study of the Elderly] (3), the first multicenter prospective cohort studies designed specifically to study adults aged 65 years and older.

At the same time, cohorts in established epidemiologic studies such as the Framingham Heart Study (4) had aged, permitting an expansion of such studies' focus to the epidemiology of disease and disability in older adults. Subsequently, it was demonstrated that older adults can be recruited to participate in intensive physiologic and clinical evaluations in cohort studies, with 4- to 6-hour examinations carried out in both centralized and home locations (5-7), and that long term retention in such studies is high. For example, after 10 years of annual examinations, the rate of cohort retention for adults aged 65 years or more in the multicen-

ter Cardiovascular Health Study was 94 percent (excluding loss to mortality). Thus, there has been a rapid change in the recognition of the need to study older adults and of the apparent feasibility of including older adults in epidemiologic studies. It is now well recognized that older adults are both willing and enthusiastic contributors to epidemiologic research.

Increasing interest in the field has been propelled, overall, by the emerging significance of the public health issues associated with the aging of the population. Not only is the US population aging, so are the populations of developed and developing countries around the world. While in 1900 4 percent of the US population was aged 65 years or older, at the end of the 20th century the proportion is over 13 percent, and it is expected to grow to over 20 percent by the year 2030 (8). In many developed countries, the proportions of persons over age 65 are already higher, while the absolute number of older adults is rising rapidly worldwide. For example, adults aged 65 years or more now constitute 12.5 percent of the US population and 14.6 percent of the Italian population, while the numbers of older adults in India and China exceed those in developed countries such as the United States (9). As part of this worldwide aging, there has been a substantially steeper rise in the rates of survivorship of the "oldest old"—persons aged 85 years and older—than in those below that age (10). In concert with these changing demographic patterns, there is concern about the increasing need for health promotion and provision of health care for an aging population—the need to plan for necessary personnel, certain types of care, and financing.

Thus, the need to understand the health status, underlying risk factors, and resulting prevention and care needs of an older population and to provide the evidence needed for promoting the health of an older population has taken its place in the forefront of public health issues for the next century. The role of epidemiology in each of these areas has been established, from description of the etiologic factors affecting the health status of older adults to analysis and evaluation of potential interventions. Overall, much of this work falls under the rubric of epidemiology as the science of

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Abbreviation: LDL, low density lipoprotein.

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prevention, with the goal of establishing a scientific basis for minimization of the illness burden now associated with aging. This has been conceptualized as the need to “compress” morbidity and disability toward the latest points in the human life span (11), permitting people who are now living longer to do so in better health. It is proposed that this could be accomplished by defining opportunities for health promotion through secondary and tertiary, in addition to primary, prevention, a spectrum that is appropriate to the range of health status in older adults (11–13). Optimally, this would result in improved quality of life and decreased health care needs and costs.

The current reality is that of an aging population that is healthier and better educated than ever before (13), and of whom 60 percent are neither disabled nor dependent (10). This suggests opportunities for vitality associated with aging that were never before envisioned on a population-based scale, and new images of healthy aging as a public health goal. Finding the means with which to accomplish such a “compression of morbidity”—helping an aging population with 15–20 years of additional life expectancy at age 65 remain robust and active until the last years of life—is the challenge to epidemiology and public health for the 21st century.

SEMINAL ACHIEVEMENTS OF THE 20TH CENTURY

While our understanding of the import of an aging population has been maturing in the latter part of the 20th century, the epidemiology of aging has developed rapidly. Descriptively, we have characterized the spectrum of diseases and health conditions affecting older adults and their prevalence, incidence, and case fatality rates. It is now recognized that health status is a function of the high prevalence of chronic diseases of aging, including arthritis in 47 percent of older adults, hypertension in 41 percent, and heart disease in 31 percent (14, 15) (table 1), as well as geriatric conditions such as falls, which affect 32 percent of adults aged 65 years or more each year (16, 17), and frailty, which has been estimated to affect 8 percent of community-dwelling older adults (and which increases with age) (18). Notably, with aging, cognitive functioning emerges as an important component of health status. While estimates vary, as many as 30 percent of adults aged 85 years or more may have dementia (19). Chronic diseases, geriatric conditions, and health habits, as well as psychosocial and economic status, are the major causes and modifiers of disability and loss of independence. The latter is a major adverse health outcome which progressively increases with aging, affecting approximately 40 percent of older adults at any given time (20).

TABLE 1. The 15 most prevalent conditions among persons aged 65 years or more in the United States

Condition	Annual prevalence* (per 1,000)
Arthritis	473
Hypertension	415
Heart disease	305
Hearing loss	294
Influenza	214
Injuries	176
Orthopedic impairment	171
Cataracts	164
Chronic sinusitis	155
Depression	147
Malignant neoplasms	145
Diabetes mellitus	104
Visual impairment	97
Urinary incontinence	88
Varicose veins	76

* Source: National Center for Health Statistics (14, 15).

The epidemiology of the diseases, conditions, and disability associated with aging has progressed rapidly through the sequential stages of epidemiologic inquiry (figure 1) in the last 30 years. One of the well-developed examples of this is the evolution of research on falls in older adults. Falling is considered a “geriatric condition,” or a condition not linked to one pathologic process, rather than a disease. In the 1970s and 1980s, falls were reported as being common among older adults but rare among younger adults (22). Falls were also shown to have serious consequences and potential physiologic and pathophysiologic, as well as environmental, etiologies that might be modifiable (figure 1, stage A) (21–23). Thus, initial work identified the import of falling for the health status of older adults and suggested that there are definable etiologies for falls. This led in 1987 to the establishment of an international working group which proposed a standardized definition of a fall (figure 1, stage B) (24). The descriptive and analytic epidemiology (stages C and D) of standardly defined falls were then reported in the late 1980s and early 1990s by a number of research groups (16, 17, 25); data indicated that one third of older adults in the community fall at least once in a given year, and that substantial rates of serious injury (24 percent of fallers) and fracture (6 percent) result from falling (16). These studies prospectively defined the risk factors for falling, which include use of sedative medications, cognitive impairment, lower extremity disability, and balance and gait abnormalities (16). In 1994, Tinetti et al. (26) reported results from a randomized trial (figure 1, stage E) of a multifactorial clinical intervention designed to reduce the risk of falling among commu-

	A. Observation of Health Concern and Impact	B. Standardized Definition	C. Descriptive Epidemiology	D. Analytic Epidemiology	E. Interventional Epidemiology Community/ Clinical Trials	F. Guidelines, Recommendations for Clinical and Public Health Practice
Stages of Investigation re: Prevention, Risk Modification						
Health Habits						
Physical Activity	✓	✓	✓	✓	✓	
Smoking	✓	✓	✓	✓		
Immunization	✓	✓	✓	✓	✓	✓
Diseases of Aging						
Colon Cancer	✓	✓	✓			✓
Cervical Cancer	✓	✓	✓			✓
Breast Cancer	✓	✓	✓			✓
Hypertension	✓	✓	✓	✓	✓	
Cardiovascular Disease	✓	✓	✓	✓		
Osteoporosis	✓	✓	✓	✓	✓	
Comorbidity	✓	✓	✓			
Geriatric Conditions						
Falls	✓	✓	✓	✓	✓	✓
Urinary Incontinence	✓	✓	✓	✓		
Frailty	✓					
Disability	✓	✓	✓	✓	✓	

FIGURE 1. Stages of epidemiologic inquiry and stages of research completed or being conducted in major areas of the epidemiology of aging.

nity-dwelling older adults. Their findings indicated that intervention in modifiable risk factors that are present decreases fall risk by 31 percent. Other studies, especially that by Wagner et al. (27), have demonstrated that a community-based risk reduction strategy also decreases fall risk. On the basis of observational and experimental epidemiologic evidence, the US Preventive Services Task Force incorporated case-finding for fall risk into its recommendations for periodic health examination in older adults (figure 1, stage F) (28).

Six findings regarding falls have generic implications for the epidemiology of aging. One is that the number of risk factors present is consistently related to the risk of falling (16, 17): Risk rises from 19 percent in the presence of one risk factor to 78 percent in the presence of four or more (16). This observation of the magnitude of the risk factor burden's affecting the likelihood of an outcome is well recognized in the etiology of chronic diseases (e.g., cardiovascular disease (29)), and in this instance was extended to geriatric conditions as well. These findings suggest that intervention designed to diminish the magnitude of the risk factor burden is an effective approach to prevention (26). Second, in almost half of all falls, falling is

observed to be the result of an interaction between host susceptibility and environmental risk exposure (16, 30); thus, risk varies with the prevalent health status of the individual. This provides a basis for stratification of analyses, as well as targeted screening strategies. Third, in fall prevention studies, the rate of reduction in fall risk varies with the underlying functional status of the population at baseline (26, 27, 31–37). This is exemplified in figure 2, which shows the reduction in falls demonstrated in a number of trials in relation to the approximate functional status of the population of older adults targeted by the intervention. Fourth, both primary and secondary prevention of falls is effective (26, 27). Fifth, given the latter two points, the outcomes sought may need to vary by health status; this approach may be essential methodologically as well, in order to identify associations that are truly present. For example, in high-functioning individuals, a continued absence of falls may be the appropriate outcome associated with maintaining higher strength, while in disabled older adults it may be a decline in the number of falls. Sixth, and finally, there are common risk factors for a number of geriatric conditions and diseases of aging, including sedentariness and associated weakness and balance and gait abnormalities (38). This

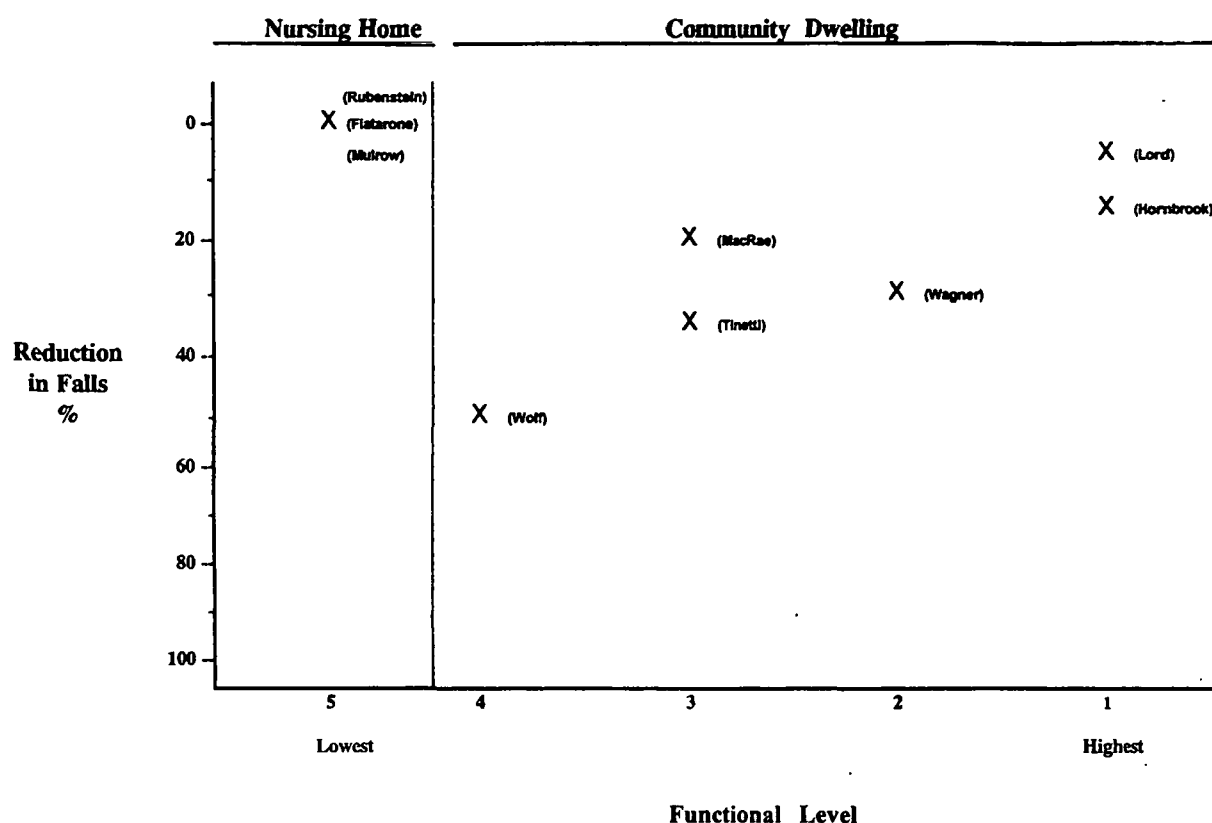


FIGURE 2. Association of exercise interventions with reduction in falls. The benefit appears to vary according to level of function of the target population. Studies included: Rubenstein et al. (31), Fiatarone et al. (32), Mulrow et al. (33), Wolf et al. (34), MacRae et al. (35), Tinetti et al. (26), Wagner et al. (27), Lord et al. (36), and Hornbrook et al. (37).

observation suggests that, in determining the population attributable risk of a risk factor, we should consider broadly the multiple outcomes it contributes to.

Other areas of research in the epidemiology of aging have gone through many, but not all, of the stages of inquiry demonstrated for falls. Figure 1 broadly summarizes the status of development of research on the roles of health habits and immunization and on some of the diseases and health conditions that are important in aging. In addition to the development of research on falls (a geriatric condition), one or two examples in each of the other categories (health habits, chronic diseases, and outcomes of disease) are highlighted here, both to emphasize specific issues and to exemplify future challenges.

In terms of health habits, much work has focused on the role of exercise and smoking in health as people age. Physical activity and the absence of smoking have been shown to be associated with greater longevity (39–41) and with lower risks of cardiovascular disease (including heart disease, stroke, and peripheral vascular disease) (42–45), cancer (46–48), respiratory diseases (48–50), and osteoporosis and hip fractures (51,

52), as well as disability (53–55) and mortality (56). Most recently, it has been shown that nonsmoking older adults live up to 5 years longer than smokers, while 3 or more years of additional life are associated with being physically active (55). Importantly, this increased life expectancy is associated with disability-free years of life, not more years of life with disability. Thus, it is now well-established that physical activity is important for promoting health into the latest years of life. Exercise is relevant to primary, secondary, and tertiary prevention; older adults at all levels of health and function can improve or maintain their exercise tolerance and strength through targeted exercise programs (57, 58). One of the implications of these observations is that loss of muscle mass and declines in exercise tolerance with age, thought to be manifestations of the intrinsic aging process, are modifiable.

A number of challenges remain to be met in completing our understanding of the role of physical activity in health for older adults. The heterogeneity in the health status of older adults has emerged as a particular challenge, and is a generic issue in studying older adults. Not only does the type of activity tolerable to

an individual vary by health status, but benefits and thus possible outcomes often vary as well. This can be seen in the outcomes of randomized trials evaluating the potential to improve strength with exercise interventions. These trials indicate that the potential for *improving* strength can be inversely associated with initial level of strength (32, 58, 59); this is similar to the findings depicted in figure 2, except that benefits appear greatest among those who are the most frail (32). Thus, both the goals of exercise and exercise modalities may need to vary by functional or health status, given the heterogeneity of health status in the older population. As with falls, measurement of the benefit accruing from exercise may require consideration of a *lack* of decline in strength in comparison with controls, as well as actual improvement—particularly in older adults who are high-functioning at baseline.

Interestingly, while epidemiologic studies have demonstrated that physical activity in older adults is associated with less disability (54, 60) and fewer years of life spent disabled (55), few experimental studies have been able to demonstrate prevention or diminution of disability, even if they can show improvements in objective performance (57). A notable exception is one trial of strength versus aerobic exercise in older adults with osteoarthritis of the knees (59), in which improvements in disability were demonstrated. Multifactorial interventions that have included physical activity have also demonstrated benefits in disability prevention (27). However, the field has not yet defined the threshold of improvements in strength and/or exercise tolerance which translates into improved function. Additionally, observational and experimental research is needed to determine whether a low or moderate level of exercise is beneficially associated with function, given that this is the level of activity older adults are most likely to participate in.

An overriding issue in studying the health status of older adults is the high prevalence of chronic conditions in older people and the resulting morbidity and disability, as well as mortality. Therefore, the focus on etiology and prevention of incident disease and premature mortality that is appropriate in young and middle-aged adults has broadened in the epidemiology of aging to include prevalent and recurrent disease, geriatric conditions, and outcomes such as disability (12) (table 2). Some of these conditions, such as falls, myocardial infarction, and stroke, present the challenge of understanding opportunities for prevention of recurrent events as well as of incident events. Most of these conditions—e.g., cardiovascular disease, osteoporosis, Alzheimer's disease, or disability—develop in a progressive fashion over a number of years and can have a prolonged latent or preclinical phase (61–63)

TABLE 2. The spectrum of preventive health care needs among older adults

Level of prevention	Targeted health issues
Primary	Incident disease, geriatric conditions
Secondary	Prevalent and recurrent disease, geriatric conditions
Tertiary	Impact of disease, geriatric conditions Morbidity Disability Health care needs Institutionalization Death

(figure 3). In some cases, the risk factors for initiation and progressive development of the condition are consistent. In other cases, they may vary with the stage of disease. It is possible that risk factors which initiate the onset of the preclinical phase may differ from those that precipitate clinical manifestations, which is analogous to our understanding of cancer etiology. There is now evidence that this may be the case for cardiovascular disease in older adults, where classic risk factors for middle-aged adults (high blood pressure, high levels of low density lipoprotein (LDL) cholesterol and glucose, smoking, and a family history of myocardial infarction) predict subclinical disease (63), while subclinical disease itself, and not these other risk factors, is the primary predictor of incident clinical events in older adults (61).

Interpretation of the implications of this epidemiologic evidence becomes especially complicated in older adults. For example, when triggers for incident events differ from the factors that predict subclinical disease, screening and intervention might need to differ depending on subclinical and clinical disease status. Continuing the example of cardiovascular disease, it appears that the relative risk for the association of LDL cholesterol with incident cardiovascular disease decreases with age—possibly a result of its proximal role in causing atherosclerosis and its lesser role in the transition from subclinical disease to clinical disease, as well as loss to mortality of those most susceptible. However, the population attributable risk associated with LDL cholesterol increases with age (64) because of the high prevalence of cardiovascular disease at the older ages. Thus, LDL cholesterol reduction may still have a benefit in prevention of cardiovascular disease on a population basis for older, as well as younger, adults. This remains to be conclusively defined, taking into account the meaning of change in relative risk with age (65).

Analogous to the findings on preclinical disease as a major risk factor for clinical cardiovascular disease,

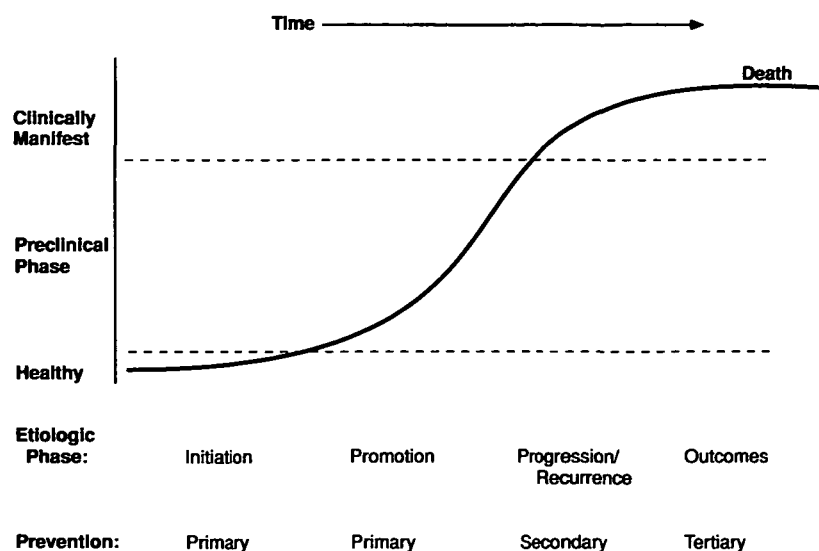


FIGURE 3. Progression of preclinical stages to clinical stages of chronic conditions, diseases, and disabilities of aging.

there is evidence that there is a preclinical phase of functional decline that predicts incident mobility disability, and that in relatively high-functioning people it is the presence of preclinical changes in function, perhaps more than underlying risk factors, that is the strongest predictor of decline in function (62, 66). Both preclinical disease and preclinical mobility disability are prevalent in older adults. The latter is present in one fifth of high-functioning women aged 70–80 years (62). In the Cardiovascular Health Study, a study of men and women aged 65 years or older, subclinical cardiovascular disease was identified in 36 percent of women and 39 percent of men overall (67), and 31 percent had evidence of subclinical stroke upon magnetic resonance imaging (63). Given the twofold increased risk of incident cardiovascular disease in persons with subclinical disease (61) and the 2- to 4-fold increased risk of incident mobility disability in persons with preclinical functional change (62), these data suggest that screening strategies which target the identification of persons with preclinical changes may be most effective in preventing these outcomes. Approaches such as these which identify high risk subsets among persons who do not have the target condition will permit the design of optimally cost-effective screening strategies appropriate to older age groups. The import of this is exemplified by the finding that the current screening recommendations for prevention of heart disease, based on LDL cholesterol level, would result in 46 percent of older adults' being eligible for lipoprotein analysis and 36 percent being eligible for intervention by National Cholesterol Education Project guidelines, if they were uniformly applied in

the older age group (68). Wholesale application of these screening recommendations, which are based on research in middle-aged adults, to all older adults would be costly (given that there are currently approximately 33 million people aged 65 years or more in the United States) and not necessarily cost-effective. Better targeting for first-line screening might occur through screening for persons with subclinical disease (61).

Thus, epidemiologic studies of older adults have demonstrated that there are subsets of risk among persons who do not have a disease condition, and that the basis for stratification may be specific to older age groups. In addition, because of changes in health status with aging, even "normal" levels of a risk factor can have heterogeneous interpretations. For example, Harris et al. (69) pointed out that a "normal" blood pressure at an older age could be found in 1) someone who has always had that low blood pressure and is truly at low risk for diseases associated with hypertension; 2) someone whose blood pressure through most of his/her life was substantially lower and for whom this "normal" pressure is actually meaningfully elevated; or 3) someone whose blood pressure, previously quite elevated, has recently decreased to "normal" levels due to heart disease and resulting compromised cardiac function. Thus, the meaning and risk associated with a "normal" blood pressure probably varies between these three groups, and these subsets may need to be delineated when outcomes of blood pressure levels are being evaluated. Despite these complexities, most studies show that elevated blood pressure in older adults confers risk, and that intervention—for systolic as well as

diastolic hypertension—is effective in preventing stroke (70, 71). Even here there is some complexity in the evidence, as a few epidemiologic studies have reported higher risk of mortality, especially short term, with lower blood pressures (72–74) in older adults. It is possible that these lower blood pressures were a result of illness present at baseline (72, 74).

The latter part of the 20th century has also seen the introduction of molecular epidemiology into the epidemiology of aging. The role of genetic characteristics in age-related diseases has been dramatically demonstrated with the identification of the apolipoprotein E genotype as a major risk factor for Alzheimer's disease in persons over 60 years of age (75). Those who are positive for apolipoprotein E have a much greater likelihood of developing Alzheimer's disease and an earlier disease onset than those without this characteristic; such persons have a 30 percent lifetime risk of developing the disease (76). These findings provide a model for considering a genetic etiology for age-related diseases, as well as the role of gene-environment interactions in the oldest age groups.

The epidemiologic study of aging has also contributed substantially to an understanding of the importance of disability as a major component of health status in older adults, in addition to rapidly increasing insight into the natural history of and etiologic factors for both the onset and progression of disability. Approximately half of severe disability in older adults occurs chronically and progressively, while the other half occurs catastrophically (77), probably as a result of events such as hip fracture, stroke, or injury. Some people who are disabled improve or recover, although the likelihood of this decreases with increasing age and severity of disability (78). Overall, 90 percent of disability results from chronic disease (79), although, as with falls, its manifestation and severity is a result of the interaction of health status with environmental demand (80–82). Comorbidity, which is present in half of older adults, plays a central role in the presence, severity, and type of disability present (83–86). There

is evidence that, in some cases, it may be the interaction between specific pairs of diseases that is the critical player in the presence of disability. Thus, disease, the outcome in etiologic research in younger age groups, becomes the key risk factor in the etiology of disability. Inferentially, decreasing not just the incidence but also the severity of disease and/or the interaction between two diseases might be the best approaches to disability prevention for older adults. There is initial evidence that such shifts may be occurring in the United States on a population basis, with increasing prevalence of many diseases as many people live longer with disease, but concurrent declines in disability rates (87, 88; V. A. Freedman and L. G. Martin, unpublished manuscript).

Health habits and lifestyle factors also play a critical role in the development of disability. There is now strong evidence that being physically active and not smoking affect quality of life into the latest age ranges (53–55, 87, 88). In addition, social factors, such as continued engagement in meaningful roles after retirement (e.g., volunteering), are protective against disability (89, 90) and even against mortality (90).

A major finding of the 20th century has been the shifting health status of the older population. In 1900, the major causes of death were infectious diseases; by the middle of the century they were chronic diseases, led by heart disease. Since 1950, while heart disease has remained the leading cause of death, there has been a dramatic decline in mortality due to heart disease—even into the oldest age groups, with declines of 58 percent, 54 percent, and 31 percent among persons aged 65–74 years, 75–84 years, and ≥85 years, respectively (8) (table 3). It is estimated that 25 percent of these declines in cardiovascular disease were due to primary prevention of disease incidence, while 29 percent was due to secondary reduction of risk factors in patients with coronary artery disease and 43 percent was due to improvements in the treatment of disease (91). These declines in rates of mortality from the leading cause of death have suggested the modifiability of

TABLE 3. Changes in mortality rates of older (aged ≥65 years) adults due to selected diseases in the last half of the 20th century, United States*

Cause of death	Age group (years)	Death rate (per 100,000 resident population)				% change, 1950–1997
		1950	1970	1980	1995–1997	
Heart disease	65–74	1,839.8	1,558.2	1,218.6	776.7	–57.8
	75–84	4,310.1	3,683.8	2,993.1	2,005.2	–53.5
	≥85	9,150.6	7,891.3	7,777.1	6,329.4	–30.8
Cerebrovascular disease	65–74	554.7	384.1	219.5	135.9	–75.5
	75–84	1,449.6	1,254.2	788.6	473.3	–65.1
	≥85	2,990.1	3,014.3	2,288.9	1,610.7	–46.1

* Source: Bureau of the Census (8).

a disease previously thought to be an inevitable concomitant of aging. Recent reports of a decline in disability of 1.1 percent per year between 1982 and 1989 (92) similarly suggest opportunities for prevention of the loss of independence we now associate with aging. At the same time, there have been marked increases in cancer mortality since 1950—increases of 23 percent, 17 percent, and 25 percent among persons aged 65–74 years, 75–84 years, and ≥85 years, respectively (8). A major contributor to this increase has been the dramatic rise in death due to cancers of the respiratory system (8). Additionally, it is anticipated that the prevalence of (and mortality from) Alzheimer's disease will increase threefold through the middle of the 21st century (93). By 2050, incident cases of dementia in the United States are projected to approach the number of incident cases of cancer (19).

There have also been major advances in both measurement and analytical methods specific to the epidemiology of aging. Methods for noninvasive measurement of subclinical cardiovascular disease have been applied to epidemiologic studies of older adults, which has provided the basis for a new understanding of risk conferred by subclinical disease (61, 67) and a new level of sophistication of biologic inquiry. In addition, standard epidemiologic methods (e.g., life table analysis) have been applied, and then extended, to the development of novel measures important in the epidemiology of aging (e.g., the measurement of active life expectancy) (55, 94–96).

Overall, this century has yielded recognition that the health status of older adults is a result of cumulative risk factor exposure; underlying aging-related biologic changes; the progressive development of impairments (subclinical and clinical) with age; the consequences of these impairments, such as disability; the risks these changes in health and function confer, such as risk for acute infection, injury, or institutionalization; and the interactions of underlying health status with acute precipitants of clinical outcomes. As a result, there is a broad spectrum of health status indicators in older adults (table 2), each stage of which has its own attendant consequences and risks. The resulting heterogeneity in health status at older ages is highly complex: Persons who are without disease would probably benefit from some very different approaches (as well as some identical approaches) to health promotion and preventive care than those who are disabled and homebound. Finally, we have learned that much of the disease, and even disability, that was previously thought to be inevitable with aging is actually potentially modifiable, and that prevention could make a substantial difference in the health status in which people live during their later years.

FUTURE DIRECTIONS

The epidemiology of aging is poised for tremendous progression, in terms of both content and methodological development. In the next generation of research, epidemiologists must complete the stages of epidemiologic inquiry for the major diseases, conditions, and disabilities of aging, as exemplified in figure 1. This work will provide the basis for the development of effective methods and guidelines for health promotion and disease prevention in older adults—guidelines which will match the spectrum of health conditions associated with aging and be appropriate for the subsets of older adults with different health statuses and vulnerabilities. For effective prevention and health promotion in an aging population, we need to ensure that the breadth of health concerns associated with aging are incorporated into prevention research and, ultimately, interventions. There are now enough data available to start making assessments (e.g., population attributable risk) of where the greatest impact can be made to promote the health of our aging population.

As each of these areas of inquiry has developed, it has become clear that there are some considerations for understanding risk and prevention in older adults which cross content areas and have methodological implications. These areas require in-depth attention. One area is the study of multifactorial risk factors, an issue that occurs frequently in the epidemiology of aging. Given the multiplicity of risk factors for gerontologic health outcomes, prevention strategies necessarily focus on decreasing the number of risk factors present, as well as on individual risk factors. In addition, effective strategies may have to prevent the synergistic interaction between risk factors, such as that between comorbid diseases. Overall, the methodologies that will be needed tend to be more complex than those used in the epidemiologic study of younger persons. This is due to the heterogeneity of health and functional status among the aged; the prevalence of subclinical disease or disability, which alters risk for future outcomes; and the fact that risk associated with a characteristic may change because of survivorship characteristics, such that an increased proportion of persons still living with a risk characteristic at age 80, for example, may be resistant to the risk factor. In addition, the study of trajectories in health status over time has to account for improvement as well as decline—in physical function, for example. In order to develop the most effective scientific bases for prevention and health promotion for an aging population in the 21st century, we must take these issues into account.

In 1991, an Institute of Medicine committee issued a report identifying the high priority research areas that they saw as “holding the greatest promise of increas-

ing knowledge of the fundamental process of aging and contributing to the quality of life of older persons" (97, p. 1826). The report identified as the first priority for epidemiologic and clinical research on aging "research on the causes, prevention, management and rehabilitation of functional disability in older persons" (97, p. 1826). It went on to say that "prevention should be highlighted, including: the interacting effects of age, lifestyle factors, and disease on disability in older persons; research to determine the effectiveness of various disease prevention strategies or practices in older persons; and studies of the relative effect of risk factors on subsequent disease or disability in older persons, as compared with younger adults" (97, p. 1826). The committee additionally recommended focusing on certain geriatric syndromes, both because of their frequent association with disability and because of the potential of research to lead to treatment. These syndromes include 1) frailty or failure to thrive, 2) impaired postural stability, 3) mismanagement of medications, 4) urinary incontinence, and 5) delirium. The second priority area included the study of the interaction of age-dependent physiologic changes and important diseases of old age, including cardiovascular disease, dementia, musculoskeletal disorders, infectious disease and diminished immunologic competence, neoplasia, and disorders of metabolism and homeostasis. The committee also identified investigative priorities for behavioral and social research central to epidemiology. These included study of the "social, psychological and behavioral variables that predict longevity and well-being in older persons, and of the most important social and psychological techniques to maintain and improve general physical and mental health and the level of functioning among older persons" (97, p. 1826). Finally, the Institute of Medicine recommended research that addresses the issues of population dynamics, including the question of whether morbidity is being postponed in proportion to increases in longevity (97). Addressing these priorities remains the overall agenda in the epidemiology of aging for the foreseeable future.

Overall, effective prevention and health promotion in the 21st century will need to target areas that, if interventions were effective, would have substantial impact on quality of life. This requires expanding beyond primary prevention to early and late secondary and tertiary prevention. Epidemiologists need to consider many more conditions that are serious, common with aging, and potentially amenable to intervention than lie within the scope of current prevention guidelines (12). For example, prevention guidelines for the future will include recommendations for prevention of disability due to chronic disease, for recurrent cardiovascular dis-

ease, and for dementia, depression, urinary incontinence, postural instability, frailty, and malnutrition, none of which are currently identified for screening in periodic health examinations (28). Recommendations for physical activity will have to be targeted and appropriate to different subsets of older adults based on their level of health and functional status. Finally, epidemiologic research in the 21st century will need to include evaluation of the behavioral factors and approaches essential to effective health promotion in older adults. Translation of this research should focus on health promotion delivery through a variety of means.

Healthy older adults—those who are particularly beneficiaries of primary prevention—are those least likely to access medical care and receive recommended screening (98). At the other end of the health spectrum, only half of disabled older women in the community appear to receive annual influenza vaccination, even though Medicare pays for this (99). New approaches are needed to ensure that the full spectrum of older adults receives appropriate health promotion. These will include classic medical and public health approaches. They may also require a new level of innovation that expands our framework for prevention to research on new types of community-based and social programs for older adults that are designed to enhance health and quality of life with aging (100). This would address, in part, another aspect of the Institute of Medicine's recommendations for a research agenda on aging: "research to examine how social structures influence the performance, productivity, health and well-being of older persons" (97, pp. 1826–7). Refining the opportunities our communities provide for older adults to remain active and productive will bring epidemiology to bear on a highly challenging and innovative aspect of research on aging.

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