Promoting Declines in the Prevalence of Late-Life Disability: Comparisons of Three Potentially High-Impact Interventions

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Although the prevalence of late-life disability has been declining, how best to promote further reductions remains unclear. This article develops and then demonstrates an approach for comparing the effects of interventions on the prevalence of late-life disability. We review evidence for three potentially high-impact strategies: physical activity, depression screening and treatment, and fall prevention. Because of the large population at risk for falling, the demonstrated efficacy of multi-component interventions in preventing falls, and the strong links between falls and disability, we conclude that, in the short run, multi-component fall-prevention efforts would likely have a higher impact than either physical activity or depression screening and treatment. However, longer-term comparisons cannot be made based on the current literature and may differ from short-run conclusions, since increases in longevity may temper the influences of these interventions on prevalence. Additional research is needed to evaluate longer-term outcomes of interventions, including effects on length and quality of life.

Keywords: Disability, aging, interventions.

WHETHER THE DECLINES IN THE PREVALENCE OF late-life disability reported over the past two decades in the United States will continue is subject to debate. Some

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researchers have suggested that continued declines are within reach (Fries 2002; Singer and Manton 1998), but others have noted that impending shifts in risk factors related to disability—such as education (Freedman and Martin 1999) or obesity (Sturm, Ringel, and Andreyeva 2004)—might make it difficult to attain continued declines. Regardless of one's view of future rates, the impending growth of the older population suggests that continued declines in the prevalence of disability are important to achieve. Indeed, an increasing number of federal initiatives have been aimed at healthy, active aging. Yet guidance for policymakers and practitioners on how to compare the population-level merits of different intervention strategies for older adults has been limited.

Comparing interventions to reduce the prevalence of disabilities requires translating evidence for individuals about risk factors and interventions into implications for the population. This article develops and demonstrates a framework for comparing these population-level effects. We review the literatures for three potentially high-impact late-life interventions: physical activity, depression screening and treatment, and fall prevention. Although we recognize the importance of considering the costs, and the cost-effectiveness, of alternative intervention approaches, we focus here on understanding the benefits of late-life interventions. Although our population of interest is the elderly U.S. population, the proposed framework may be used for any group, however geographically, socially, or economically defined.

The Framework

The Disablement Process and Illustrative Trajectories

One of the most often cited conceptual frameworks for understanding the disablement process, developed by the Institute of Medicine (Pope and Tarlov 1991), defines pathology, impairment, and functional limitation as deficits at the cellular, organ, and person level, respectively. Disability is defined as a limitation or inability to perform socially defined activities and roles in an environmental context. This model has been further refined to distinguish between underlying disability (without personal or technological assistance) and actual disability (with assistance if used) (Verbrugge and Jette 1994). A more recent approach

embodied in the International Classification of Functioning, Disabilities, and Health takes explicit account of contextual factors—the individual's health condition, the environment, and other personal factors—that may influence an individual's ability to participate in meaningful activities (World Health Organization 1999).

Our proposed approach draws on these efforts and conceptualizes disability as the inability to carry out daily activities independently, without help from another person. We thus conceptualize changes to the environment, including the use of assistive devices and environmental modifications (e.g., the use of a walker, addition of grab bars, or addition of curb cuts in the neighborhood), as reducing disability if they allow an individual to perform daily activities independently. In theory, we are interested in participation in a broad set of activities, but in practice, research and policy generally measure late-life disability in terms of activities of daily living (ADLs)—self-care tasks such as bathing, dressing, and getting in and out of bed—and instrumental activities of daily living (IADLs)—tasks that facilitate independent living such as shopping, cooking, and managing money. Although most of the recent declines have been in IADL disability (Freedman, Martin, and Schoeni 2002), ADL disability is also important to consider because it often requires more intensive, and more expensive, care arrangements (Spillman 2004).

To illustrate the effect of interventions on the disablement process, we draw upon the IOM framework and the notion of illness trajectories (Lunney et al. 2003; Lunney, Lynn, and Hogan 2002; Lynn 2001; Murray et al. 2005). The three trajectories in figure 1 suggest pathways of the disablement process for three “typical” people. The horizontal lines represent thresholds between states of the disablement process: someone whose trajectory lies between the dashed and solid lines has a functional limitation but no disability, and someone who has fallen below the solid line has a disability. Death corresponds to the trajectory line reaching the horizontal axis. Thresholds may vary across individuals and may change over time.

At one extreme, for example, people who reach age sixty-five and develop lung or colon cancer ordinarily decline rapidly. In contrast, individuals who develop frailty, dementia, or a disabling stroke will likely experience a slow and steady decline in functioning. A third group of individuals, with organ system failures such as congestive heart failure, will lose functioning slowly, with intermittent exacerbations. Note that the

FIGURE 1. Illustration of Three Prototypical Trajectories of the Disablement Process

length of life with a disability (corresponding to the number of years that the trajectory is below the solid horizontal line) is typically much longer for someone with frailty or dementia (five years on average) than for a person who dies of cancer or organ failure (two to three years on average). These three trajectories reflect the experience of about 85 percent of the older population (Lunney et al. 2003; Lunney, Lynn, and Hogan 2002; Murray et al. 2005); the remaining 15 percent includes persons with pathways that are less common (e.g., individuals who die suddenly with no period of disability) and more complex (e.g., individuals with lifelong disabilities and those who had debilitating accidents earlier in life).

Risk Factors and Interventions

Risk factors increase disability by influencing a person's chances of developing disease, having functional limitations, experiencing the onset or recovery from disability, or dying. Modifiable risk factors, those that interventions can change, are of particular interest and may include behavioral, medical, social, and environmental factors. Although some risk factors, such as smoking or inactivity, respond to intervention at the individual level, other factors, such as the social and physical environment, are generally beyond one person's control and therefore may respond only to broader targeting. Most research has focused on the former. In a review of seventy-eight longitudinal observational studies, Stuck and colleagues (1999) found strong evidence for a dozen or so modifiable risk factors for the onset of a disability, almost all at the individual level. Among the strongest predictors were depression, limited physical activity, and a constellation of factors that increase the risk of falling (e.g., cognitive

FIGURE 2. Illustration of Two Interventions for an Individual Experiencing Frailty Trajectory

impairment, lower body strength and coordination limitations, and sensory impairment).

Interventions may target one or more risk factors and may modify risks at any point along the disablement process. The literature describes three general approaches: *primary*, defined as avoiding the onset of pathological processes that may eventually lead to disability; *secondary*, defined as slowing the progression (and thereby postponing debilitating effects) of disease; and *tertiary*, defined as strategies to restore function and increase autonomy in people with reduced functional capacity (Pope and Tarlov 1991). Such strategies may be targeted at individual-, family-, or other group-level risk factors, for example, through community-based or practitioner-focused efforts.

Figure 2 illustrates two ways that an intervention may alter the disablement process for someone on the most common trajectory (Lunney et al. 2003; Lunney, Lynn, and Hogan 2002): the slow and relentless decline associated with frailty, dementia, and disabling strokes. A program to increase physical activity targeted at a frail older person, for example, may promote strength and balance and lead to the avoidance of an injurious fall, resulting in an alternative pathway (dashed trajectory line) and fewer years lived with disability. In contrast, a home modification after an injurious fall—say the addition of grab bars and a seat in the shower—may shift the disability threshold (dotted horizontal line), thereby allowing an individual to quickly regain his or her independence in daily activities and also to spend fewer years with a disability.

A third possibility (not shown) is that an intervention may affect both disability and mortality. In that case, the length of the trajectory also might be changed (e.g., by lengthening the trajectory associated with

organ failure), or this person may shift from one trajectory to another (e.g., avoiding cancer and experiencing the longer-lived frailty trajectory).

Information Needed to Compare Interventions

Comparisons of interventions to promote the decline of disability are complicated by several factors. First, most randomized studies evaluate interventions in terms of their influence on one or more proximate risk factors for disability, rather than on disability itself. Thus, to assess short-run effects, one must consider three pieces of information—the prevalence of the risk factor of interest, the effect of the intervention on the targeted risk factor, and the relationship between the risk factor and the disablement process. Second, a variety of disability measures are used in the few intervention studies that do evaluate disability as an end point and in studies of the association between risk factors and disability. Thus, the information available for comparing effects across studies and across interventions is less than ideal, and the effects of interventions on disability often cannot be precisely calculated. Third, because interventions may influence not only disability but also length of life, their short- and long-term effects may differ. Despite these complications, however, the relative magnitude of effects on the prevalence of disability can be assessed by comparing interventions according to the following dimensions: the size and selectivity of the intervention's target population, the risk of disability associated with the risk factor addressed by the intervention, the effect of the intervention on the targeted risk factor, and the influence of the intervention on length of life and competing risks.

Size and Selectivity of the Target Population

To assess the population-level effects of an intervention, first consider the prevalence of the risk factor(s) that it targets. There often is a trade-off between the effectiveness of an intervention and the size of the target population; that is, the less targeted an intervention is, the more people it will reach, but its effects may be diluted. Ideally, estimates of risk factor prevalence rely on national population-based samples that allow for generalizable statements, but in practice estimates may be available from only small, nonrepresentative clinical samples. To assess

longer-term effects, one also must be aware of any impending changes in the size and composition of the targeted population.

The Relationship between the Risk Factor and the Risk of Disability

Next consider the strength of the relationship between the targeted risk factor and the disablement process. Reports generally state such estimates as relative risks (the ratio of risks of developing a disability for someone with and without the given risk factor), ideally adjusted for other coexisting risk factors. Because the prevalence of disability is a function of incidence, recovery, and mortality processes, interventions that influence the rate of disability incidence or recovery also influence disability prevalence. Note, however, that disability may be due to more than one factor, with potential synergies across risk factors. Hence, interventions that target only one risk factor (e.g., reducing environmental barriers by installing grab bars without addressing depressive symptoms) may have more modest effects on disability than do those that target multiple causes.

The Effect of Intervention on Risk Factors

Another important consideration is the likely effect of an intervention on the targeted risk factor(s). Trials usually determine how interventions affect one or more proximate risk factors for disability—for example, the relative risk for inactivity, falls or fall-related injuries, or depression remission—over a relatively short period of time (e.g., weeks or months). These reports generally address *efficacy*—that is, how much the risk factor is reduced under controlled circumstances. The ultimate *effectiveness* of the intervention in reducing the risk factor is a function of efficacy, adherence to the protocol, and differences between the study's subjects and the target group in the population.

The Influence of an Intervention on Length of Life and Competing Risks

Longer-run comparisons require understanding the intervention's effect on not only disability but also length of life and what proportion of additional years is free from disability. The issue of competing risks

arises mainly for interventions targeted at the prevention of diseases with an earlier age of onset. For example, if successful, interventions designed to prevent cancer or organ failure would allow more people to live longer. If these extra years followed the typical trajectory of frailty, then such interventions could result in disability ultimately becoming more prevalent.

Application of the Framework

We applied this framework by reviewing the literature for three different types of interventions targeted at older adults: efforts to improve physical activity, depression screening and treatment programs, and multifactor fall prevention programs. To select these interventions, we used a Delphi method, in which twelve experts were asked to rank twelve interventions (exercise, improved chronic disease care, fall prevention systems, depression screening and treatment, stroke prevention, home modifications, assistive devices, dietary changes, joint/organ replacements, smoking cessation, cognitive training, and improved care planning) along four dimensions: short-term effect on disability, long-term effect on disability, effect on length of life, and size of population affected. The initial twelve interventions met the following criteria: they addressed a modifiable risk factor for disability; were in use in practice but were not already widespread; had some published evidence demonstrating their efficacy; and, if implemented, could within a few years reduce disability in older people (rather than being targeted at younger and middle-aged people and requiring decades for late-life effects to be known). Experts also could write in their own suggestions. The three approaches reviewed here (i.e., strategies to address inactivity, depressive symptoms, and falls) scored especially well on the rankings and also involved especially large numbers of older adults with the relevant risk factors (Freedman et al. 2005).

Studies were located through searches of MEDLINE, Ageline, Cochrane Library, EBM Reviews, CINAHL, and Psych Abstract using the Reed and Baxter approach (Reed and Baxter 1994). Searches used the following terms: "outcome assessment (health care)," *or* "intervention studies," *or* "treatment outcome," *and* one of the following terms: "exercise," "exercise therapy," "depression," *or* "accidental falls/prevention and control." Two analysts subsequently examined the abstracts to determine

their suitability for more detailed review. They selected only randomized control trials that included adults aged sixty and older and that also had clearly defined randomization procedures, and reviews of such trials. For each study that met these inclusion criteria, we summarized the design, intervention, outcomes, and results (relative risks indicating efficacy) (table 1), and we evaluated adherence and generalizability. We also searched for and reviewed observational studies to determine the prevalence of relevant risk factors and their associations with disability incidence, recovery, and prevalence.

Results

We begin by comparing the effects of intervention approaches on factors related to disability prevalence in the short run (table 2, columns 3 through 5) and then discuss the literature in light of additional factors germane to the longer term (table 2, columns 6 and 7).

Size of Target Population

All three of the intervention approaches could reach a sizable target population. About 51 percent of persons aged sixty-five or older reported having no physical activity (U.S. Department of Health and Human Services 2000), or about 19 million of the estimated 37 million persons aged sixty-five and older in 2006. Nearly 30 percent of Americans aged sixty-five or older—more than 10 million people—have some depressive symptoms, with 2 to 3 percent having major depression (Beekman et al. 1997; Roberts et al. 1997). Each year, about one-third of people aged sixty-five or older, or nearly 12 million people, experience falls (Hausdorff, Rios, and Edelberg 2001; Hornbrook et al. 1994).

Risk of Disability Associated with Each Risk Factor

In a given year, about 10 percent of the older population will experience the onset of disability and about 20 to 25 percent of those who develop a disability will recover within a year (Fried and Guralnik 1997; Leveille et al. 2000). Inactivity, depression, and falling all increase in varying degrees the risk of developing a disability in late life. For example,

TABLE 1
Summary of Randomized Controlled Trials (RCTs) and Review Articles by Type of Intervention

Intervention	Intervention Studies Reviewed	Interventions	Outcomes	Efficacy			Sample Composition/Generalizability
				Reducing Risk Factor	Reducing Disability	Adherence Rates/Issues	
Exercise	RCT: 38 Reviews: 4	Aerobic exercise	Strength, aerobic capacity, flexibility, walking, standing, balance	Consistently positive effects of aerobic exercise on physiologic outcomes	Inconsistent (5–7 relative risk of disability incidence given intervention in one study)	60%–90% over time	Subjects often healthy or have arthritis; some older with physical frailty
		Strength or endurance training Quadriceps training Walking					
Depression screening	RCT: 10 Reviews: 2	Screening and feedback/referral	Recognition of depression Rates of treatment	Strong effect on recognition (RR = 2–3), inconsistent or small effect on remission (RR = .87–.90), small effect on treatment (1.2)	—	Not applicable	Relatively few studies with older subjects

Depression treatment	RCT: 13 Reviews: 1	Antidepressants Combination therapies	Risk of remission Risk of recurrence	Moderate to strong effect on remission of meds (RR = 1.2–1.8) and of combined treatment vs. meds only (RR = 1.4)	Potentially moderate effect on disability (change of 1.71 on 12-item physical component summary and –.15 on IADL scale)	60%–80%	Relatively few studies with older subjects
Fall prevention	RCT: 77 Reviews: 3	Single component (exercise)	Fall rate, injury rate, performance on balance tests	Inconsistent evidence of effect on fall rate	—	Unknown	Samples small and often not diverse
		Multi-component	Fall rate, injury rate	Moderate (.5–.7 relative risk of falling)	Moderate (.6–.8 relative risk of injurious fall)	Unknown	Samples small and often not diverse
		Population based	Fall rate, fall-related hospital admissions	Small and not significant (reduction in fall rate of 0.07 falls per person per year [OR = 0.95])	Small to moderate (relative reduction in fall-related fractures of 6%–33%)	Not applicable	Studies conducted outside United States (Sweden, Denmark, Australia, Norway)

Note: Following standard conventions, an effect size of 0.2 or less was considered weak; between 0.2 and 0.8, moderate; and above .8, strong. An odds ratio (OR) or relative risk (RR) of 1.2 or less was considered weak; up to 1.8, moderate; and over 1.8, strong.

TABLE 2
Comparisons of Three Potentially High-Impact Interventions with Factors Related to Late-Life Disability Prevalence

Short-Term Considerations					Additional Longer-Term Considerations	
Intervention (1)	Risk Factor(s) Targeted (2)	Size of Target Population in Millions (%) (3)	Effect of Risk Factor on Risk of Disability Incidence (4)	Likely Effectiveness of Intervention on Risk Factor (5)	Trends in Age-Specific Rates of Risk Factor (6)	Effects of Intervention on Mortality (7)
Physical activity/ exercise	Inactivity, lack of endurance, lack of strength	19 (51%)	2.0	Moderate (in part due to poor adherence)	Decreasing	Possibly small to moderate
Depression screening and treatment	Unrecognized/ untreated depression	10 (30%)	1.5–2.0	Moderate (in part because change in risk of treatment small)	Treatment increasing	Possibly small to moderate
Multi- component, individualized fall prevention	Falls and risk factors for falls, including muscle weakness, balance deficits, cognitive impairment, home hazards	12 (33%)	2.0–3.0	Moderate	Decreasing	Possibly small

inactivity doubles the risk of developing a disability, whether defined as an ADL or IADL difficulty, an inability to perform activities without help, or low scores on physical performance tests (Miller et al. 2000; Seeman et al. 1995; Simonsick et al. 1993; Wang et al. 2002). The existence or onset of depressive symptoms raises by one and a half to two times the risk for incident disability as measured by self-reports of mobility, ADL and IADL dependence, and physical performance tests (Lenze et al. 2001; Penninx et al. 1998; Penninx et al. 1999b). Finally, approximately 20 to 25 percent of older people who fall experience severe injuries or limitations (Gillespie et al. 2003; Nevitt, Cummings, and Hudes 1991; Nevitt et al. 1989; Tinetti et al. 1995; Tinetti, Speechley, and Ginter 1988; Tinetti and Williams 1998). This figure includes fractures, trauma to the head, serious lacerations, and joint dislocation or injury, as well as curtailing of activities because of a fear of falling. Consequently, larger relative risks of disability—on the order of 2 to 3—are evident for individuals experiencing falls.

Efficacy of Interventions

Comparing the efficacy of interventions is difficult because study populations often are selective but not fully described; rates of study adherence and withdrawal often are not reported; and outcome measurements vary widely. Moreover, when disability measures are included as outcomes, they often are not fully defined. With these caveats in mind, we next summarize the evidence regarding the efficacy of each approach.

Exercise. Most interventions involve aerobic exercise alone or compared with resistance training, strength or endurance training, or quadriceps training. The definitions of these terms vary greatly. Some samples consisted mainly of older adults with functional limitations, disability, or arthritis, although most studies were small with short follow-up periods (generally from six weeks to two years). Adherence rates generally ranged from 60 to 90 percent, depending on the protocol, although the longer-term rates were much lower (Hauer et al. 2003).

In general, exercise reduced impairment and improved functioning (Bearne, Scott, and Hurley 2002; Binder et al. 2002; Chin et al. 2001; Deyle et al. 2000; Hurley and Hagberg 1998; King et al. 2000; Mangione et al. 1999; Marchionni et al. 2003; Mitchell et al. 2001; O'Reilly, Muir,

and Doherty 1999; Penninx et al. 2001; Rydwick, Frandin, and Akner 2004), usually in already physically compromised target populations. In contrast, the review articles suggest that the impact of exercise on *disability* is inconsistent (Keysor 2003; Keysor and Jette 2001; Latham et al. 2003). At least one study found, however, that randomization to an aerobic or resistance exercise protocol reduced the risk of ADL disability onset by 40 to 50 percent compared with those in the control group, with the larger effects at more intense levels (Penninx et al. 2001). And a preventive home-based physical therapy program (including progressive balance and conditioning exercises) had modest but consistent effects on functional decline in physically frail older persons (Gill et al. 2002; Gill et al. 2004). One challenge in implementing the preventive physical therapy program in a frail elderly population was that many participants were unable to advance beyond the initial exercise levels (Gill et al. 2003).

Depression Screening and Treatment. We reviewed both screening and treatment interventions. The screening interventions were designed to increase the recognition and treatment of depression by providers and thus to change the providers' behavior. These programs varied in intensity. Some interventions screened patients for depression and gave the results to their primary care physician. Other strategies were screening and feedback with provider education, treatment advice, or more integrated recognition and management approaches as part of quality improvement systems. Outcomes generally included the percentage of depression cases recognized by providers, rates of treatment among those identified, and rates of depression at follow-up.

A review of fourteen studies (Pignone et al. 2002) indicates that in the adult population screening programs increased recognition of depression two to three times compared to usual care; most of these studies reported a relative increase of 10 to 47 percentage points in recognition rates. But the effect of screening and feedback on receiving treatment and on rates of depression at follow-up was mixed. More integrated interventions that included provider education and treatment recommendations had stronger effects than did programs of screening and feedback alone. Meta-analysis suggests that overall, screening and feedback interventions reduced the risk for persistent depression by 10 to 13 percent ($RR = 0.87-0.90$), but only two of the seven studies included in this analysis were targeted at older adults and neither yielded statistically significant reductions of depression.

The treatment interventions we reviewed included antidepressant medications for major geriatric depression and combinations of medications and psychosocial/psychotherapeutic treatments. The trials reported various outcomes, such as recognition of depression, rates of treatment, and rates of remission and/or recurrence. Depression generally decreases adherence to treatment regimes (DiMatteo, Lepper, and Croghan 2000; Pampallona et al. 2004). In analyses of a trial with older adults, 18 to 22 percent of subjects did not follow the treatment protocol (Reynolds and Kupfer 1999; Reynolds et al. 1999). A comprehensive review of sixteen studies with samples of adults of all ages (some including older adults) found that the combined nonresponse and dropout rates for medication averaged 46 percent (ranging from 0 percent to 71 percent), and for medication and therapy they averaged 36 percent (range: 11 percent to 55 percent) (Pampallona et al. 2004).

A number of pharmacological agents appear to provide benefit in older populations (Mulsant et al. 1999; Tollefson et al. 1995; Williams et al. 2000). Two randomized controlled studies of combined psychotherapy and medication (nortriptylene) involving older people demonstrated a large beneficial effect over three years (Reynolds and Kupfer 1999; Reynolds et al. 1999), with a relative risk of recurrence of 0.22 (20 percent for combined therapies versus 90 percent for clinic visits and placebo). A review of sixteen clinical trials with adult samples found that the treatment had a strong effect on the risk of remission (Pampallona et al. 2004). Studies focusing on functional outcomes typically had small samples with small improvements after treatment or remission, usually in instrumental activities of daily living or in cognitive functioning (Butters et al. 2000; Callahan et al. 2005; Chemerinski et al. 2001; Heiligenstein et al. 1995). Recently, Callahan and colleagues (2005) found moderate improvements in physical functioning (change of 1.71 on the twelve-item physical component summary and $-.15$ on an IADL scale) in patients randomized to receive treatment from a depression clinical specialist coordinating with the primary care physician.

Fall Prevention. We reviewed single interventions, multi-component interventions, and systematic reviews of such interventions. We included both interventions targeted at older individuals (Chang et al. 2004; Cumming 1998; Gillespie et al. 2000; Hill-Westmoreland, Soeken, and Spellbring 2002; McClure et al. 2005; Wolinsky, Fitzgerald, and Stump 1997) and population-based efforts implemented in other countries at

the community level (McClure et al. 2005). The most common single intervention tested was physical activity (see the earlier section on exercise). Multi-component interventions usually combined education about risks with exercise, home safety, and health assessments. These studies rarely addressed the issue of subjects' adherence to the fall prevention protocols. The population-based interventions varied but generally involved a combination of coordinated community-wide efforts to educate the community, reduce hazards in homes and communities, train health care personnel, and/or visit the homes of high-risk individuals. The primary outcome measures were fall rates, injury rates from falls, performance on balance tests, and hospitalizations resulting from fall-related fractures or injuries. According to a review by McClure and colleagues (2005), the extent of community exposure to the intervention was systematically assessed in only one of five community-based efforts.

Multi-component studies that adopted a comprehensive fall assessment and an individualized management program reduced the risk of falling by between 0.29 and 0.36 (relative risk 0.5 to 0.7) (Close et al. 1999; Ray et al. 1997; Steinberg et al. 2000; Tinetti et al. 1994; Wagner et al. 1994), although the follow-up periods were generally short. Of the ten studies in a recent Cochrane review with fall injuries as an outcome, six studies (one multifactor and five exercise/physical therapy interventions) showed those randomized to the intervention had 0.67 to 0.77 times the risk of experiencing a fall-related injury compared with those in the control groups (Gillespie et al. 2003). Although the evidence for population-based strategies was limited, a review of five prospective community trials with matched control communities suggested that despite the methodological limitations, fall-related fractures potentially could be reduced by 6 to 33 percentage points (McClure et al. 2005).

Shifting Target Populations

Several demographic trends influence predictions of the future effectiveness of strategies in reducing disability at the population level. The most obvious is that the U.S. population is aging. By 2020, 14.1 percent will be aged sixty-five or older (compared with 10.9 percent in 2000), and 2.2 percent will be aged eighty-five or older (compared with 1.5 percent in 2000) (U.S. Census Bureau 2004). The composition of the older population is shifting as well. Over the next two decades, the older population will have on average more years of education (Freedman and

Martin 1999) and be more racially and ethnically diverse (U.S. Census Bureau 2004). Several health-related trends also affect predictions. Most notably, obesity (Sturm, Ringel, and Andreyeva 2004) and related cardiovascular diseases such as diabetes (Freedman and Martin 2000) have been steadily increasing, although the net effects of these changes are unclear. On the one hand, better educated persons may comply better with protocols and invest more in their future well-being. On the other hand, the greater diversity and comorbidities of the older population will continue to challenge population-wide interventions.

The risk factors reviewed here also show trends. Inactivity has been declining (DiPietro 2001), and depression treatment has been rising (Harman et al. 2003). The number of injuries caused by nonfatal falls may have decreased (NIH 1996), although age-specific rates of hip fracture appear to have increased (Samelson et al. 2002). Despite the changes, these risk factors are likely to remain important over the next few decades.

Influence on Mortality and Competing Risks

Longer-run comparisons require understanding an intervention's effect on length of life and the number of additional years free from disability. All three intervention approaches can affect the risk of mortality. The relative risk of mortality given depressive symptoms or falls, for example, ranges from about 1.5 to 2.0 (Dunn et al. 1992; Penninx et al. 1999a; Schulz et al. 2000), whereas inactivity increases the risk of dying between two and two and a half times (Simonsick et al. 1993). Our review of the late-life interventions literature suggests that few studies measured mortality as an end point. Moreover, the follow-up periods were generally too short to determine whether the period of disability for the group given the intervention would ultimately be longer or shorter relative to the control group.

Discussion

This article has proposed and applied a new framework for comparing strategies to reduce the prevalence of late-life disability. In the short run, three factors—the size of the target population, the effect of the targeted risk factor on disability, and the effect of the intervention in changing the risk factor's distribution—are especially important to consider.

Although comparisons of three potentially high-impact interventions based on this framework do not provide quantified evidence of an unambiguously preferred strategy, on balance the evidence suggests that in the short run, prevention of falls through multi-component strategies would likely have a greater effect than would exercise or depression interventions alone. Reasons include the strong link between falls and disability, the sizable yet targeted population at risk for injurious falling, and the greater efficacy of multi-component fall prevention strategies over single-component strategies in averting falls and their resulting injuries. However, comparisons of longer-term effects, which depend on the intervention's interaction with mortality and competing risks for disability, also are important for policymakers to consider and could yield different conclusions. Our review highlighted the need for additional research to evaluate interventions' longer-term outcomes, including effects on length as well as quality of life.

Our application of the framework to the existing literature was limited in several respects. Although we reviewed interventions targeted at older adults, interventions introduced earlier in life ultimately may have a greater effect on the prevalence of late-life disability. Moreover, the available research did not permit us to quantify the impact of the selected interventions on cross-sectional disability rates or isolate the likely influence of interventions on rates of dependence in ADLs, for which care-related costs are substantial. To provide such comparisons, microsimulation models that integrate data from multiple sources may be needed. Finally, we did not consider the variability of costs across intervention approaches. It may be that individually tailored interventions cost more per person than do single intervention approaches, but whether they are more or less expensive relative to their benefits is not clear. Future analyses could build on our efforts here and consider both the costs and the benefits of various intervention approaches.

Nevertheless, based on the framework and literature review, we can recommend to policymakers general approaches that are likely to have a high impact on disability at the population level. Disease prevention strategies that target trajectories with relatively short periods of disability before death are unlikely to result in declines in the prevalence of disability. Indeed, they might increase the prevalence of disability in the long run if more of each cohort shifts to trajectories with longer-than-average periods of disability. In contrast, interventions aimed at enhancing the independence of older, frail adults are more likely to

reduce the prevalence of disability in the short term. Combining clinical strategies to manage physical and mental health conditions, to avoid injuries, and to alter the home environment of frail older adults might be an especially effective combination, particularly if combined to target the individualized needs of persons just entering the frailty trajectory.

To date, randomized trials of home-based interventions aimed at averting or delaying functional decline among older adults have yielded mixed results. According to a recent review (Stuck et al. 2002), home-based multidimensional assessments with follow-up have modestly reduced the incidence of disability and functional decline (RR, 0.76; 95 percent CI, 0.64–0.91). These benefits, however, generally were for people younger than eighty. But because these trials also reduced mortality by similar amounts, the ultimate effect on the prevalence of disability in the long run remains unclear. Our proposed framework highlights several issues that might shape these home-based efforts by identifying physical, social, and environmental components likely to have a substantial impact on the prevalence of disability in both the short and the longer run.

Whether combining community-focused interventions with individual-level approaches would be more effective in reducing disability prevalence is unclear. Although the preliminary evidence suggests a benefit from intervening at the community level to prevent falls, community-based efforts have been less attractive to U.S. policy-makers in the past than those focused on individual behaviors (Raphael and Bryant 2005). Future research efforts should consider not only which interventions but also which level or levels of implementation are likely to be most effective.

Our review highlighted four important gaps in knowledge that should be considered when designing and refining multifactor strategies to prevent disability. First, no comprehensive study examines the physical, social, and environmental causes of disability; consequently, which combinations of interventions would have the largest impact on reducing disability rates are not clear. Second, studies have often omitted measures of disability and instead measured proximate risk factors for disability and have generally failed to evaluate longer-term outcomes, including the complex interactions with mortality. Lengthening the follow-up periods of intervention studies and adding measures of mortality and clearly defined measures of disability would permit more confident predictions. Third, disability reduction hinges in part on people's ability to make and sustain behavioral changes, whether by using different services,

modifying their environments, or changing their daily routines. Future work should be aimed at improving understanding of adherence issues in older populations. Fourth, the frail elderly often are left out of clinical studies examining disability interventions. Clinical trials should remedy this omission and seek ways to include this group (Ferrucci et al. 2004).

Although this article has emphasized design issues, policymakers also must consider implementation issues. Chief among them is that the existing health care delivery and financing system does not promote optimal functioning but instead focuses on treatment and, to some degree, the prevention of disease. For example, many components of a multi-component program targeted at individuals—such as assistive devices, home modifications, strength training or exercise programs, and home safety—do not generally fall under the purview of physicians but require coordination with other therapists and social services. Moreover, these elements often are not covered by Medicare or Medicaid and thus are not accessible to poorer segments of the older population who are at especially high risk for developing disability. Future research should consider how best to finance and deliver a multi-component disability intervention. Ideally, the evaluation of such an approach should assess proximate risk factors and disability and should track the subjects long enough to determine their effects on length of life. Only with this kind of study can policymakers structure investments to diminish the prevalence of disability.

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