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Exercise Comes of Age: Rationale and Recommendations for a Geriatric Exercise Prescription

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THERE has been a gradually growing awareness among policy makers and health care professionals during the past several decades of the importance of appropriate exercise habits to major public health outcomes, resulting in numerous position stands and policy recommendations that include physical activity prescriptions (1–12). However, there is still skepticism among some clinicians and investigators as to the actual potency of exercise for disease and/or disability prevention and treatment, particularly in already frail or near frail adults (13). It is likely that some of the discrepancies among research findings, clinical practice, and policy recommendations result from a lack of appreciation of the heterogeneity of the terms "exercise" and "physical activity" as they are used in the literature. Posing the question "Does exercise prevent or treat disease in older persons?" is analogous to asking "Does medication prevent or treat disease in older persons?" The answer only makes sense when exercise is described in terms of its modality, dose (frequency and intensity), duration of exposure, and compliance with the prescription, and in relation to a specific disease, syndrome, or biological change of aging. In addition, it does not necessarily follow that the same type or dose of exercise is needed for treatment of overt or advanced disease as that which would be required for prevention. Such observations are obvious to clinicians when thinking about surgical, pharmacological, or nutritional management of disease, but lack of explicit training in exercise physiology for most physicians has often obscured this point in discussions of the value of exercise for geriatric health care problems.

Therefore, in the sections that follow, a rationale for the use of exercise and physical activity for health promotion and disease prevention is offered. Exercise will be discussed in terms of the specific modalities and doses that have been studied for their role in the physiological changes of aging, disease prevention, and treatment of older persons with chronic disease and disability. Finally, an overview of the current recommendations, reflective of the current consensus of knowledge, is provided. Gaps in knowledge and controversial areas requiring further study are identified.

The interaction of physical activity, exercise, and physical fitness with health and aging is complex and multifaceted. Although many questions remain about mechanisms of effect and dose-response curves (14), a synthesis of the literature indicates many potentially positive effects of participation in physical activity on the aging process. Any discussion of these issues must begin with definitions of the terminology. Physical activity has been traditionally defined as any bodily movement produced by contraction of skeletal muscle that substantially increases energy expenditure, although the intensity and duration can vary substantially (15). It should be noted that some forms of physical activity that may have particular relevance to an aging population (e.g., balance training) may not conform to this standard definition. This activity may be performed in leisure or occupational hours, and surveys for the older adult should capture both paid and unpaid (volunteer) work (16). Exercise is a subcategory of leisure time physical activity in which planned, structured, repetitive bodily movements are performed, with or without the explicit intent of improving one or more components of physical fitness. Physical fitness is defined as a set of attributes that contribute to the ability to perform physical work (e.g., cardiorespiratory endurance, muscle power, balance, flexibility, and body composition) or influence health status. "Metabolic fitness" has been advanced more recently as a term that encompasses a range of biologically important adaptations to exercise (increased insulin sensitivity, lipoprotein lipase activity, etc.) that may contribute to health status, but do not directly affect exercise capacity.

Therefore, to understand the potential role of exercise in the aging process and to incorporate it into clinical practice, health care professionals should understand the risks and benefits of various modalities and doses of exercise and categories of physical activity in relation to specific health-related goals. Recent attempts have been made to synthesize this vast literature (14) into discreet recommendations, and in most areas the consensus was that more research is required to define minimum thresholds of efficacy as well as optimal doses and modes of activity participation for health outcomes. However, despite the need for more knowledge in some areas, sufficient evidence exists from both observational studies and randomized controlled trials to define the most promising areas of benefit for older adults.

In this brief review, a rationale for the incorporation of physical activity and exercise into the health care of an aging population is based on an overview of the literature available to date. This rationale can be divided into four broad themes, each of which will be discussed in the sections that follow:

(i) Regular participation in physical activity or exercise can minimize the physiological changes associated with typical aging in a sedentary society as well as contribute to psychological health and well-being;
(ii) Regular participation in physical activity or exercise increases longevity and decreases the risk of many common chronic diseases;
(iii) Regular participation in physical activity or exercise may be used as primary or adjunctive treatment for certain chronic diseases and may counteract specific side effects of standard medical care;
(iv) Regular participation in physical activity or exercise may assist in the prevention and treatment of disability.

Evidence That Exercise Can Minimize the Physiological Changes Associated With Typical Aging and Contribute to Psychological Health and Well-Being

Slowing Biological Changes of Aging That Impair Exercise Capacity

There is a great similarity between the physiologic changes that are attributable to disuse and those that have been typically observed in aging populations, leading to the speculation that the way in which we age may be modulated with attention to activity levels (17). An overview of some of the most important physiological changes associated with aging or disuse is presented in Table 1. As can be seen, these effects span a wide range of organ systems and functional capacities potentially relevant to health status in older adults. Not all changes attributed to the aging process will impact directly on exercise capacity, however. For example, some of the most visible changes we recognize as aging, such as changes in hair color and volume, altered skin texture and elasticity, reductions in height, and even changes in speed of cognitive processing and retention of new information, will have little direct impact on the ability to exercise or continue to perform activities of daily living (ADLs) independently in advanced years. In most physiologic systems, the normal aging processes do not result in significant impairment or dysfunction in the absence of pathology and under resting conditions. However, in response to a stress or significant disuse, the age-related reduction in physiologic reserves causes a loss of homeostatic balance, or the inability to complete a task requiring near-maximal effort.

Although changes in maximal work capacity (aerobic fitness, or maximal oxygen consumption) will be immediately noticeable and disastrous for an elite athlete (18–22), they may accrue insidiously in nonathletic populations over many years without much effect on daily life. This is because most sedentary individuals rarely call upon themselves to exert maximal effort in physical domains. Thus, subtle changes in physical activity patterns over the adult life span allow most people not engaged in athletic pursuits to lose a very large proportion of their physical work capacity before they even notice that something is wrong or find that they have crossed a threshold of disability (23). Women are particularly susceptible here, because their initial reserve of muscle mass is so much lower than that of men, due to gender differences in anabolic hormonal milieu (24–26) as well as lifestyle factors. They will therefore cross this threshold where losses of musculoskeletal capacity impact on functional status at least 10 years before men do in most cases (27).

Another important consequence of age-related changes in physiologic capacity is the increased perception of effort associated with submaximal work [a lowering of the anaerobic threshold, or the approximate level at which significant dyspnea occurs (28)]. For example, between youth and middle age, an untrained man or woman may find that walking briskly results in increased blood pressure, heart rate, respiratory rate, and an earlier sense of overall and leg muscle fatigue than previously (29). This changing physical capacity has the unfortunate negative side effect of increasing the tendency to avoid stressful activity. Such behavioral change compounds the sedentariness caused by changing job requirements or retirement, societal roles and expectations, and other psychosocial influences (30). Thus, a vicious cycle is set up: "usual" aging leading to decreasing exercise capacity, resulting in an elevated perception of effort, subsequently causing avoidance of activity, and finally feeding back to exacerbation of the age-related declines themselves secondary to the superimposition of disuse on biological aging.

Many studies suggest that chronic adaptation to physical activity can markedly attenuate decrements in exercise capacity that would otherwise occur with aging (see Table 1), with the notable exception of maximal heart rate [due to declining sensitivity to beta-adrenergic stimulation in the aging heart (31)]. Although peak exercise workload achievable is therefore always lower in aged individuals, the cardiovascular and musculoskeletal adaptations to chronic aerobic exercise (32–37) enable the trained individual to sustain higher submaximal workloads with less of a cardiorespiratory response (heart rate, blood pressure, and dyspnea), as well as less overall and musculoskeletal fatigue. Thus, apart from peak athletic performance, the adaptations to cardiovascular training can overcome much of the day-to-day functional limitations that might otherwise be imposed by the physiological changes of aging and disuse (38).

Musculoskeletal function (strength, power, muscle endurance) is dictated largely by the size of the muscle mass that is contracting, and to a lesser extent by changes in surrounding connective tissue in the joint (cartilage, tendons, and ligaments) and neural recruitment, conduction velocities, and fatigue patterns. Sedentary individuals lose large amounts of muscle mass over the course of adult life (20–40%), and this loss plays a major role in the similarly large losses in muscle strength observed in both cross-sectional and longitudinal studies (25,39–41). However, unlike many other changes that impact on exercise capacity, muscle mass cannot usually be maintained into old age even with regular aerobic activities in either general populations (42) or master athletes (43). Only overloading of muscle with weight lifting exercise (resistance training) has been shown to largely avert losses of muscle mass (and also strength) in

Table 1. Physiological Changes of Aging Modifiable by Exercise

Physiological Parameter	Aging/Disuse Effect	Physical Activity/Exercise Effect
Exercise/Work Capacity		
Maximal aerobic capacity	Decrease	Increase
Heart rate and blood pressure response to submaximal exercise	Increase	Decrease
Maximal heart rate	Decrease	No change
Tissue elasticity	Decrease	Increase
Muscle strength, power, endurance	Decrease	Increase
Motor coordination	Decrease	Increase
Neural reaction time	Decrease	Increase
Oxidative and glycolytic enzyme capacity, mitochondrial volume density	Decrease	Increase
Gait speed, step length, cadence, gait stability	Decrease	Increase
Cardiovascular Function		
Resting heart rate	No change	No change or decrease
Maximal cardiac output	Decrease	Increase*
Endothelial reactivity	Decrease	Increase
Maximal skeletal muscle blood flow	Decrease	Increase
Capillary density	Decrease	Increase
Arterial distensibility	Decrease	Increase
Vascular insulin sensitivity	Decrease	Increase
Plasma volume, hematocrit	No change, decrease	Increase
Impaired baroreflex function, postural hypotension in response to stress	Increase	Decrease
Pulmonary Function		
Vital capacity	Decrease	No change
Maximal flow rates	Decrease	No change, increase
Nutritional Status		
Resting metabolic rate	Decrease	No change, increase
Total energy expenditure	Decrease	Increase
Thermic effect of meals	Decrease, no change	Increase, no change
Total body water	Decrease	Increase
Total body potassium, nitrogen, calcium	Decrease	Increase
Protein synthesis rate, amino acid uptake into skeletal muscle, nitrogen retention, protein turnover	Decrease	Increase
Gastrointestinal transit time	Decrease	Increase
Appetite, energy intake	Decrease, no change	Increase, no change
Metabolic, Miscellaneous		
Glycogen storage capacity, glycogen synthase, GLUT-4 transporter protein content, and translocation to membrane	Decrease	Increase
Lipoprotein lipase activity	Decrease	Increase
Total cholesterol, LDL cholesterol	Increase	Decrease or no change
HDL cholesterol	Decrease or no change	Increase or no change
Hormonal and sympathetic nervous system response to stress	Increase	Decrease
Growth hormone, IGF-1	Decrease	Increase, no change
REM and slow wave sleep duration	Decrease	Increase
Heat and cold tolerance, temperature regulatory ability	Decrease	Increase
Cognitive processing speed, accuracy	Decrease	No change, increase
Attention span	Decrease	Increase
Memory	No change, decrease	No change
Glomerular filtration rate	Decrease	No change

Notes: LDL = low-density lipoprotein; HDL = high-density lipoprotein; IGF-1 = insulin-like growth factor 1; REM = rapid eye movement. Aging/Disuse effects are not completely separable in most studies. Direction of effects represents a synthesis of the findings in a majority of the available observational and experimental data in each domain.

*Due to changes in exercise-augmented cardiac contractility and stroke volume; observed only in endurance-trained men so far.

older individuals (44). In this study, Klitgaard and colleagues found that elderly men who swam or ran had similar measures of muscle size and strength as their sedentary peers, whereas the muscle of older men who had been weight lifting for 12–17 years was almost indistinguishable, and even superior in some aspects, to healthy men 40 to 50 years younger than them.

Appropriate progressive resistance training programs of 3–6 months in duration can be shown to increase muscle strength by an average of 40–150%, depending on the subject characteristics and intensity of the program, and to increase total body lean mass by 1–3 kg, or muscle fiber area by 10–30% (45–53). Thus, even if some of the neural control of muscle and absolute number of motor units remaining is not affected by exercise, the adaptation to muscle loading, even in very old age (54), causes neural, metabolic, and structural changes in muscle, which can compensate for the strength losses, and in some cases the atrophy, of aging. There is some controversy as to whether or not there are significant gender differences in the functional or hypertrophic response to resistance training in elders. Some studies have found women to have smaller gains in muscle strength and power (55) or hypertrophic response (56) to training, whereas others have found no differences (53,57,58) or even greater gains in women (59). It is likely that differences in training regimens and measurement techniques used to assess muscle mass, cross-sectional area, or volume may explain some of these discrepant results. More research is needed to refine training techniques and cointerventions (nutrition, hormones, etc.) so as to maximize these adaptations in both men and women.

Clearly, habitual exercise has the potential to lessen the impact of biological aging on two of the major elements of exercise capacity: aerobic fitness and muscle strength. Similarly, there is evidence that balance training (60–63) and flexibility training (1,64) induce adaptations in associated declines in these areas. As noted in Table 1, many other cardiovascular and metabolic parameters with important implications for health status (65) are also responsive to alterations in physical activity levels (66,67).

Optimization of Body Composition With Aging

There are many reasons to integrate exercise into the conceptual model of healthy aging, but clearly one of the most potent pathways from physical activity to health status involves the modulation of body composition by habitual exercise patterns (68). The typical patterns of change in body compartments seen in "usual aging" are outlined in Table 2. The extent to which these changes occur in an individual depends upon a combination of genetic, lifestyle, and disease-related factors that are all interrelated (69,70). All of these nutritional and body composition changes may negatively impact metabolic, cardiovascular, and musculoskeletal function (71–73), even in the absence of overt disease, and therefore it is important to anticipate them and optimize lifestyle choices and other treatments that can counteract the negative effects of aging and/or disease on body composition.

One can categorize chronic diseases and geriatric syndromes that are potentially modifiable by exercise if an underlying derangement in body composition is addressed. For example, a stabilization or increase in bone mass in pre- and postmenopausal women is achievable by either resistive (74–78) weight-bearing aerobic exercise (79–84) or high-impact loading (77,85). Such effects on bone density (differences of 1–2% per year associated with exercise) may be important for both prevention and treatment of osteoporosis and related fractures and disability, as reviewed in several recent meta-analyses (86–90). Even if exercise alone is an insufficient stimulus to maintain bone density at youthful levels, the combination of exercise effects on bone strength, muscle mass, muscle strength, and balance should lower the risk of injurious falls substantially in physically active individuals. However, randomized controlled trials of any exercise modality with osteoporotic fracture itself as a primary outcome remain to be conducted.

Decreases in both total adipose tissue accumulation and its abdominal (visceral) deposition are achievable by both aerobic (91–93) and resistive training (94–96), with significant changes in total body fat usually only in conjunction with an energy-restricted diet (97–99). Preferential visceral fat mobilization is often seen in response to exercise and dietary interventions (100–103), which means that small amounts of total body weight or fat mass (5%) may be associated with substantial changes in visceral fat (25% or more), with important metabolic implications for the prevention or treatment of the insulin resistance syndrome (99,104). Such prevention of excess adiposity is both protective and therapeutic for many common chronic diseases, offering significant risk reduction in the case of osteoarthritis; cardiovascular disease; gall bladder disease; type 2 diabetes; breast, colon, and endometrial cancer; hypertension; stroke; and vascular impotence, for example (8,105–109). Although generalized obesity is associated with excess mortality, cardiovascular disease, osteoarthritis, mobility impairment, and disability, it is predominantly excess visceral fat that is associated with the derangements of dyslipidemia, elevated fibrinogen, hyperinsulinemia, glucose intolerance or diabetes, vascular insulin resistance, hypertension, and cardiovascular disease.

An increase in muscle mass, in contrast to changes in fat and bone, is only achievable to a significant degree with progressive resistance training or generalized weight gain from extra energy and protein consumption (46,49,50,110, 111) and has a potential role in prevention of diabetes (112–115), functional dependency (26,116–118), and falls and fractures (119–124), as well as being important in the treatment of chronic diseases and disabilities (24), which are accompanied by disuse, catabolism, and sarcopenia. For some diseases, like type 2 diabetes mellitus, there are potential advantages to both minimizing fat tissue as well as maximizing muscle tissue, because these compartments have opposite and likely independent effects on insulin resistance in the elderly (99).

Promotion of Psychological Well-Being

Psychological well-being is vital to optimal aging and is dependent on a host of factors, including genetic traits, so-

Table 2. Body Composition Changes With Aging and Exercise Recommendations

Body Compartment	Age-Related Change	Exercise Modality Recommended
Adipose tissue	Increased adipose mass	Aerobic or resistance training
	Increased visceral and truncal deposition	
Skeletal muscle	Decreased skeletal muscle mass	Resistance training
	Preferential atrophy/loss of type 2 (fast twitch) fibers	
	Increased intramuscular fat and connective tissue (decreased muscle quality)	
Bone	Decreased bone mass, density	Weight-bearing aerobic exercise
	Increased bone fragility	Resistance training
		High-impact, high-velocity loading of affected skeletal sites

cial support systems, personality types, and the presence of positive and negative psychological constructs such as happiness, optimism, morale, depression, anxiety, self-esteem, self-efficacy, and vigor. Physical activity participation has been shown to be associated with more positive psychological attributes and a lower prevalence and incidence of depressive symptoms in cross-sectional and prospective epidemiological studies (125,126) and experimental trials (127–134). It is notable that effects are most significant in those with comorbid illness, such as cardiovascular or pulmonary disease (132) or major depression (130,134–137), attesting to the clinical relevance of this exercise adaptation.

Evidence That Exercise Increases Longevity and Prevents Common Chronic Diseases

The effects of exercise on total mortality are unlikely to ever be substantiated via randomized controlled clinical trials, given the impracticality of random assignment to various physical activity regimens over the course of a lifetime. However, there is clear evidence of an inverse, linear dose-response relationship between the volume of physical activity reported in epidemiological studies (with sample sizes ranging from less than 500 to more than 2.5 million individuals) and all-cause mortality rates (138–141). These relationships are demonstrable for both men and women, and for older (older than 60 years or age) as well as younger cohorts (142–147). Volumes of energy expenditure during exercise of at least 1000 kcal/week reduce mortality by about 30%; reductions of 50% or more are seen with volumes closer to 2000 kcal/week (138), or when more precise measures estimates of physical activity participation incorporating fitness assessments are utilized instead of surveys (139,148). Despite the consistency of the data from well-designed observational studies, many questions still remain regarding the minimum threshold for efficacy; the effect of exercise intensity, duration, and frequency (apart from contributions to overall volume); the effect of nonaerobic modalities of exercise; and the mechanism of benefit. From a public health perspective, if small, effective doses of moderate intensity activity are found to be as beneficial as longer bouts of vigorous activity, adoption of mortality-reducing physical activity recommendations by sedentary middle-aged and older adults may be more successful. Of particular relevance to the geriatric exercise prescription are studies that have demonstrated that a change from a sedentary to more active lifestyle in midlife or beyond is associated with a reduction in mortality (143,149,150).

Although preventive medicine is often conceptualized as most relevant to young or middle-aged adults, it is increasingly acknowledged as central to the optimal health care systems approach to elderly individuals as well. Changes in lifestyle, environmental hazards, and earlier recognition and treatment of potential risk factors for chronic diseases have resulted in a larger proportion of the population reaching old age without overt disease or disability (151). Others may present with advanced disease in some systems, but with potential for primary or secondary prevention evident in other areas. Thus, both healthy and chronically ill older adults are candidates for preventive strategies that will lessen the burden of comorbidity, disability, and premature death caused by incident disease. Seen in this light, preventive medicine is an appropriate goal in both fit community-dwelling and frail institutionalized elders as a means to improved quality of life and a reduction in the personal and societal burden of chronic disease management.

As can be seen from the diagram in Figure 1, physical activity patterns may be influenced by aging and genotype, and physical activity in turn may influence physiological capacity, psychological health, dietary intake, other adverse behaviors, or risk factors for chronic disease. All of these are potential pathways by which exercise could ultimately influence the prevalence of chronic disease in a population. Other than genetic factors and environmental insults (pollution, asbestos, heavy metals, infectious agents, etc.), most of the major contributors to the development or severity of chronic diseases are in some way related to habitual levels of physical activity. Examples would include cardiovascular disease (152,153), stroke (154), type 2 diabetes (115,155), obesity (156,157), hypertension (158–160), osteoarthritis (161), depression (130,133,137,162), and osteoporosis (4, 163–167). A notable exception to these patterns are the diseases of the central nervous system (e.g., Parkinson's disease, dementia, other degenerative neurological diseases), which have not been substantively linked etiologically with exercise or physical activity. The bi-directional nature of the relationships depicted in Figure 1 indicates that appropriate levels of physical activity may optimize such risk factor profiles; on the other hand, the presence of risk factors may lead to reduced physical activity and thus heightened risk of disease. For example, inactivity may lead to sarcopenia, followed by muscle weakness and further restriction in activity levels, subsequently contributing to the development of osteopenia and gait abnormalities, and finally hip fracture.

The vast majority of the evidence linking exercise to chronic disease prevention is drawn from the epidemiological literature, as might be expected given the long latency period required for the development of most of these diseases. Examples include a reduced risk of cardiovascular disease, type 2 diabetes, osteoporosis, stroke, breast cancer, colon cancer, and depression, as well as disability itself (168–173) in more physically active or fit individuals. For example, in the largest prospective cohort study of its kind, 72,488 female nurses from the Nurses' Health Study (aged 40–65) were followed for 8 years for health status and physical activity levels. Increasing dose and intensity of physical activity (including walking) was strongly inversely correlated with risk of incident stroke, particularly ischemic stroke. Habitual exercise reduced the disease risk by 40–50% at the highest levels, compared with sedentary women, similar to protective effects seen for type 2 diabetes and cardiovascular disease (115,142,143,155,174) in this and other studies. Importantly, a change in physical activity level in mid- or late life was protective, with each 3.5 hour/week increase in moderate or vigorous activity over baseline associated with a 29% reduction in the incidence of ischemic stroke. This finding suggests a relatively immediate benefit of changes in lifestyle, giving support to the use of exercise as preventive medicine, even among elderly or high-risk individuals. Although such observational studies can never

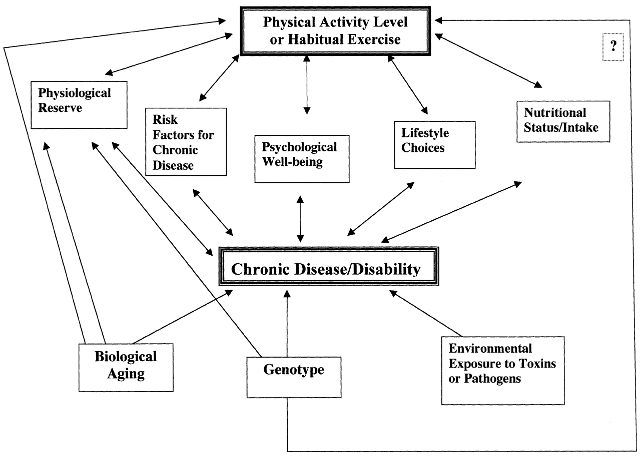

Figure 1. Model depicting pathways by which physical activity or habitual exercise level may influence the development or expression of chronic disease and disability in adulthood. Note that most arrows are bi-directional, indicating that the presence of a chronic disease or risk factor may itself feed back and alter habitual physical activity levels, thereby aggravating the effect of sedentariness on disease risk. Lifestyle choices include drug and alcohol abuse, smoking, and risk-taking behavior. Physiological reserve includes such factors as body composition (muscle mass, bone mass, fat mass), insulin sensitivity, immune competence, protein synthesis, and muscle strength and power. Environmental exposures include pollution, chemicals, drugs, allergens, noise, radiation, ultraviolet light, and infectious agents, among others. Genotype is postulated to influence physiological reserve, ability to adapt to physical training, as well as possibly propensity to engage in physical activity.

completely separate the effects of physical activity from genotype or other unmeasured characteristics of individuals who self-select an active lifestyle, the best studies attempt to control for demographic differences and other known risk factors for the incident disease and to eliminate early or occult disease at baseline, if possible prior to analysis. So, for example, exercise reduces the risk of cardiovascular disease by approximately 50%, even after controlling for such risk factors as smoking, obesity, hypertension, and dyslipidemia. Because exercise likely works in part by reducing the presence or severity of these risk factors, the true protective effect of exercise may thus be greater than that represented by its "independent" effect on disease incidence.

Longitudinal cohort studies have generally confirmed the cross-sectional data linking exercise to reduced disease risk. Of particular interest are studies such as that by Blair and colleagues (143), in which middle-aged sedentary adults with low fitness levels have become fit at follow-up and have markedly reduced cardiovascular mortality compared to those remaining unfit or inactive. These findings suggest that preventive exercise prescriptions instituted in middle age or beyond may be as important as those initiated at younger ages.

Randomized clinical trials are better able to eliminate the bias inherent in observational studies, in which physical activity levels are self-selected. Such data are now available for prevention of some disease states (cardiovascular disease, diabetes mellitus, and falls) but are not yet available for others (stroke, osteoporotic fracture, depression). One recent example is the Finnish Diabetes Prevention Study (115). In this trial, 523 adults with impaired glucose tolerance were randomized to usual care or a combination of exercise and dietary advice to lower weight and visceral fat. The experimental group had a 58% reduction in the incidence of type 2 diabetes over 3 years of follow-up. Among those who exercised but did not achieve the nutritional weight loss goals, there was an 80% reduction in the incidence of diabetes, suggesting the potency of a change in exercise pattern alone in diabetes prevention, even in very high-risk adults. Similarly, in the Diabetes Prevention Program (a randomized controlled trial of 3234 individuals with impaired glucose tolerance) (175) participants randomly assigned to the intensive lifestyle intervention of diet (goal of 7% weight loss) and exercise (150 mi/wk) reduced their risk of incident type 2 diabetes by 58% in 2.8 years. Of particular interest is the finding that those older than 60 responded best, with a 71% reduction in the development of diabetes.

In another example of secondary prevention, Posner and colleagues (176) have reported a reduced incidence of recurrent cardiovascular events in older adults participating in long-term outpatient aerobic exercise compared with sedentary controls. Campbell and colleagues have reported a series of randomized controlled trials of falls prevention in women older than the age of 80, for whom balance and strength training and home-based walking programs reduced falls incidence over 2 years by 30–40% (177–179). Similarly, Rubenstein and colleagues have reported that a low-moderate intensity program emphasizing strength, endurance, balance, and mobility increased physical activity levels, while reducing activity level-adjusted fall rates after 3 months in elderly men at risk (180).

The appropriate use of exercise as a preventive strategy should include recognition of potentially modifiable risk factors for chronic diseases, as well as choice of the appropriate modality and dosage of exercise needed to accomplish the goal. The major diseases and syndromes for which exercise may be beneficial as a preventive prescription are listed in Table 3, along with the underlying risk factors that are targeted (the postulated mechanisms of exercise benefit) and the specific modality of exercise most relevant for these goals. In many cases, it is not known precisely how exercise works, as it can be seen to exert protection even when known risk factors are controlled for in analyses. For example, exercise reduces the risk of ischemic stroke in women, even after controlling for age, family history of cardiovascular disease, hypertension, smoking, body mass index, and consumption of fruit and vegetables (154).

Evidence for the Role of Exercise in the Treatment of Disease

There are many ways to conceptualize the integration of exercise into the treatment of established disease. Traditional medical interventions don't typically address disuse syndromes accompanying chronic disease, which may be responsible for much of their associated disability. Exercise is particularly good at targeting syndromes of disuse and may significantly impact on disability without altering the underlying disease itself in any primary way. Examples

Table 3. Choice of Exercise Modality for Chronic Disease or Geriatric Syndrome Prevention

Disease or Syndrome	Suggested Mechanisms of Exercise Effect	Recommended Exercise Modality
Arthritis	Decreased body weight	Aerobic
	Maintenance of cartilage integrity	Resistance training
	Maintenance of muscle and tendon strength	
Cancer (breast, colon, prostate)	Decreased body fat	Aerobic
	Decreased estrogen levels	
	Altered dietary intake	
	Decreased gastrointestinal transit time	
	Increased prostaglandin F_2	
Chronic renal failure	Decreased blood pressure	Aerobic
	Decreased type 2 diabetes mellitus	Resistance training*
Congestive heart failure	Decreased blood pressure	Aerobic training*
	Decreased myocardial infarction	Resistance training*
	Decreased type 2 diabetes mellitus	
Coronary artery disease	Decreased blood pressure	Aerobic training
	Decreased LDL cholesterol	Resistance training*
	Increased HDL cholesterol	
	Decreased fibrinogen	
	Decreased total body fat, visceral fat	
	Decreased insulin resistance, hyperinsulinemia	
	Decreased cortisol levels	
	Increased adherence to smoking cessation, dietary behaviors	
	Decreased depression, anxiety	
Depression	Increased self-efficacy, mastery	Aerobic training
	Internalized locus of control	Resistance training*
	Decreased anxiety	
	Improved sleep	
	Increased self-esteem	
	Increased social engagement; decreased isolation	
	Decreased need for drugs associated with depression (beta-blockers, alpha-blockers, sedative-hypnotics)	
	Decreased body fat, improved body image	
Frailty, disability	Increased muscle mass	Aerobic training
	Increased muscle strength	Resistance training*
	Increased overall physical activity level	
	Decreased depression	
	Increased self-efficacy	
	Improved nutritional intake	
	Improved protein utilization from diet	
	Reduced polypharmacy	
Gout	Decreased obesity, visceral obesity	Aerobic training*
		Resistance training*
Impotence	Decreased blood pressure	Aerobic training*
	Decreased type 2 diabetes mellitus	Resistance training*
Mobility impairment, falls	Increased strength	Aerobic training
	Improved balance	Resistance training
	Improved gait stability	Balance training
	Increased self-efficacy	
	Decreased fear of falling	
	Decreased depression	
	Increased muscle mass	
	Decreased fat mass, body weight	
Osteoporosis	Increased bone density	Resistance training
	Increased tensile strength	Aerobic training
	Increased muscle mass	Balance training
	Improved gait stability and balance	
	Improved nutritional intake (energy, protein, calcium, vitamin D)	
	Reduced fear of falling, improved self-efficacy	
	Increased overall activity levels, mobility	
	Decreased need for drugs associated with postural hypotension, falls, hip fractures (antidepressants, antihypertensives, sedative-hypnotics)	
Stroke	Decreased obesity	Aerobic training
	Decreased blood pressure	Resistance training*
	Decreased cholesterol	

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Table 3. Choice of Exercise Modality for Chronic Disease or Geriatric Syndrome Prevention (*Continued*)

Disease or Syndrome	Suggested Mechanisms of Exercise Effect	Recommended Exercise Modality
Type 2 diabetes mellitus	Improved insulin sensitivity	Aerobic training
	Increased GLUT-4 protein and translocation to membrane sites	Resistance training
	Reduced visceral fat mass	
	Decreased cortisol response to stress	
	Improved dyslipidemia	
	Decreased blood pressure	
	Increased muscle mass	
Urinary stress incontinence	Improved pelvic floor muscle strength	Resistance training (Kegel exercises)
	Improved mobility	Balance training

Notes: LDL = low-density lipoprotein; HDL = high-density lipoprotein.

*Indicates that data at present are primarily drawn from observational or experimental studies of the effect of the specific exercise modality on the *risk factors* for the disease or syndrome.

would include Parkinson's disease (181,182), chronic obstructive pulmonary disease (183,184), intermittent claudication (185), and chronic renal failure. Exercise may also lower the risk for recurrences of a disease, such as secondary events in patients with cardiovascular disease (8,176) or prevention of recurrent injurious falls in an individual after a hip fracture. Some pathophysiological aberrations that are central to a disease are specifically addressed by exercise, which may therefore serve as an adjunct to standard care. For example, losses of visceral fat achieved through resistive or aerobic training improve insulin resistance and complement dietary and pharmacological management of type 2 diabetes in the older adult with central obesity (157,186). Exercises designed to stimulate skeletal muscle hypertrophy in congestive heart failure (46,187,188) provide benefit that counteracts the catabolic effects of circulating cytokines in this disease (189) and is not achievable with cardiac medications alone. Functional improvements in individuals with arthritis (161,190,191) who are given quadriceps exercises improve joint stability and may thus add to the benefits of antiinflammatory and analgesic medication (192). Finally, exercise may counteract undesirable side effects of standard medical care, a use of exercise that is just emerging in the literature. Such use of exercise would include resistance training for patients receiving corticosteroid treatment to counteract the associated proximal myopathy and osteopenia (193–195), neutralizing the adverse effects of energy-restricted diets in obesity (96,196) or protein-restricted diets in chronic renal failure (45), for example. Table 4 identifies diseases for which there is the most robust evidence of benefit for the use of therapeutic exercise, along with suggestions for the most effective modalities. Table 5 outlines examples of exercise used as an adjunct to counteract the side effects of standard medical care and thus potentially improve overall disease and quality-of-life outcomes in such patient groups.

Exercise and the Prevention and Treatment of Disability

There are many ways in which physical activity may influence the development and expression of disability in old age. These theoretical relationships are now borne out in many epidemiological investigations and provide the rationale for both the experimental studies and exercise recommendations that are found in many recent reviews of this topic (168,197–200). For example, 1097 participants from the Established Population for Epidemiologic Studies of the Elderly study sites who were not disabled at baseline were analyzed for factors related to disability-free survival until death in old age (201). Physically active adults were more likely to survive to age 80 or beyond and had approximately one half the risk of dying with disability compared to their sedentary peers.

The most obvious conclusion from a review of the literature in this area is that there is a great deal of overlap between the identifiable risk factors for disability and the consequences or correlates of habitual inactivity (17,24,170, 202,203). At the most basic level, shared demographic characteristics between those at risk of disability and those more likely to exhibit sedentary behavior include advanced age, female gender, non-Caucasian ethnicity, and lower educational level and income. Psychosocial features common to both cohorts include social isolation, low self-esteem, low self-efficacy, depressive symptoms, and anxiety. Lifestyle choices more prevalent in disabled and/or inactive adults include smoking and excess alcohol consumption. Body composition changes associated with both functional decline and inactivity include sarcopenia, obesity, visceral obesity, and osteopenia. Exercise capacity is typically reduced in both conditions in all domains, including aerobic capacity, muscle strength, endurance and power, flexibility, and balance. Gait instability and slowness, as well as impaired lower extremity function and mobility, characterize both disabled and inactive populations. Because most studies have not assessed the full complement of factors known to be associated with disability, and many have made observations at a single point in time, it is not possible to say with certainty how all of these complex relationships fit together, which relationships are causal, and which risk factors are independent of each other.

In addition to the associations above, chronic diseases associated with inactivity, such as obesity, osteoarthritis, cardiovascular disease, stroke, osteoporosis, type 2 diabetes, hypertension, and depression, are all risk factors for disability as well. In some cases, data linking inactivity to disability-related diseases are available from cross-sectional or prospective cohort studies as well as experimental trials [e.g., diabetes (204–207), cardiovascular disease (8,152,

Table 4. Exercise and Disease Treatment

Disease State	Exercise of Choice	Considerations
Arthritis	Aerobic	Low impact
	Resistance training	Sufficient volume to achieve healthy weight if obese
Chronic insomnia	Aerobic	Exercise in afternoon to maximize effects
	Resistance training	
Chronic obstructive pulmonary disease	Aerobic	Resistance training may be more tolerable in severe disease; combined effects complementary if feasible
	Resistance training	Time exercise sessions to coincide with bronchodilator medication peak
		Use oxygen during exercise as needed
Chronic renal failure	Aerobic	Exercise reduces cardiovascular and metabolic risk factors, improves depression
	Resistance training	Resistance training offsets myopathy of chronic renal failure
Congestive heart failure	Aerobic	Resistance training may be more tolerable if dyspnea severely limits aerobic activity
	Resistance training	Cardiac cachexia targeted by resistance training
Coronary artery disease	Aerobic	Complementary effects on exercise capacity and metabolic profile from combined exercise modalities
	Resistance training	Resistance training may be more tolerable if ischemic threshold is very low due to lower heart rate response to training
Depression	Aerobic	Moderate- to high-intensity exercise more efficacious than low-intensity exercise in major depression
	Resistance training	Minor depression may respond to wider variety of exercise modalities and intensities
Hypertension	Aerobic	Small reductions in systolic and diastolic pressures seen
		Larger changes if weight loss occurs
Obesity	Aerobic	Sufficient energy expenditure to induce deficit
	Resistance training	Resistance training maintains lean tissue (muscle and bone) better than aerobic training during weight loss
Osteoporosis	Aerobic	Aerobic exercise should be weight-bearing
	Resistance training	High-impact, high-velocity activity (e.g., jumping) potent if tolerable
	Balance training	Resistance training effects are local to muscles contracted
		Balance training should be added to prevent falls
Peripheral vascular disease	Aerobic	Vascular effect is systemic, upper limb ergometry may be substituted for leg exercise if necessary
		Resistance training has positive but less robust effect on claudication
		Need to exercise to the limits of pain tolerance each session to extend time to claudication
Venous stasis disease	Aerobic	Local muscle contractions stimulate return of fluid via lymphatic system
	Resistance training	Utilize lower body training, elevate legs when possible

176)], and in other cases from epidemiological data alone [colon and breast cancer (208,209)]. For some diseases, disability is complex and not fully explained by deficits in physical capacity such as strength and balance, and other pathways may be operative, including sensory function, glycemic control, and other aspects of health status (204).

Notable exceptions to patterns linking inactivity to disability are visual impairment and dementia, which are not directly related to inactivity, but are highly significant risk factors for disability in elders. This does not mean that exercise plays no role once these conditions are present, however. On the contrary, the inability to modify these pathological contributors to the disability process means that the focus should be on attempting to compensate for them by maximizing function in other domains. So, for example, someone with significant visual impairment from macular degeneration may benefit from strength and balance training to minimize fall risk even more than someone with intact vision.

In summary, the theoretical model that describes the potential role of physical activity in the development of disability is complex and not completely understood. It is likely that exercise exerts its effects through multiple pathways simultaneously, and it is not clear that a single mechanism of action is dominant, even within a given disease paradigm. It is clearly not as simple as impairments leading to functional limitations and ultimately disability. For example, impairments in strength explain less than 20% of the variance in lower extremity physical performance in the Women's Health and Aging Study (210). Depressed individuals may be disabled without any impairment in physical capacity. Conversely, the use of adaptive devices such as motorized wheelchairs and environmental modifications may allow completely paralyzed individuals to function without disability.

Very few studies have examined a variety of physiological factors and activity in the same cohort, so it has been difficult to attribute differential risk to various impairments in exercise capacity. For example, Laukkanen and colleagues (211) reported that in 291 80-year-olds residing in the community in Finland, difficulty with ADL functioning was explained in part by muscle strength, balance, and upper extremity flexibility, but not aerobic capacity. Cross-sectional data from the ongoing Women's Health and Aging Study (212) indicate that in 1002 disabled community-dwelling women older than 65, there is an inverse relationship between disability and physical activity levels and knee extension and handgrip strength at baseline, and these factors contribute independently to the severity of the disability. These authors have proposed a spiraling deterioration process, in which motor disability, contributed to by age, chronic disease, and knee pain, leads to a reduction in physical activity, which in turn causes muscle strength to decrease and further disability to emerge. Foldvari and colleagues measured muscle strength, endurance, and power, as well as aerobic capacity, physical activity level, psychological status, and health conditions in 80 disabled community-dwelling women (213). Although upper and lower body strength and power, aerobic capacity, and physical activity level were all related to functional dependency in univariate analyses (as well as self-efficacy, depression, and burden of disease), only leg extension power and physical activity

Table 5. Counteracting Iatrogenic Disease With Targeted Exercise Prescriptions

Disease(s)	Standard Treatment	Unintended Side Effect	Exercise Recommendation
Acute or chronic pain syndromes	Narcotic analgesics	Constipation	Aerobic training Progressive resistance training
Chronic renal failure Chronic liver disease	Low-protein diet	Decreased lean body mass Decreased albumin Diminished growth hormone, IGF-1 Muscle weakness	Progressive resistance training
Congestive heart failure Atrial fibrillation	Digoxin	Anorexia	Progressive resistance training Aerobic training
Coronary artery disease Hypertension Parkinson's disease Incontinence Depression, insomnia Congestive heart failure Edema	Alpha- and beta-blockers, calcium channel blockers, anticholinergics, antidepressants, diuretics, other cardiac medications	Orthostatic hypotension, falls, hip fractures	Progressive resistance training Aerobic training Balance training
Depression	Antidepressants (tricyclics, selective serotonin reuptake inhibitors)	Postural hypotension, falls, hip fractures	Balance training Progressive resistance training
Edema Congestive heart failure Hypertension	Diuretics	Urinary incontinence	Kegel pelvic floor isometric strengthening exercises
Epilepsy	Anticonvulsants	Osteomalacia Osteoporosis	Progressive resistance training Weight-bearing aerobic training High-velocity, high-impact loading (e.g., jumping)
Fracture of appendicular bone	Casting, immobilization in splint	Muscle atrophy Osteopenia	Isometric contractions under cast while immobilized Progressive resistance training after removal of cast
Hypertension	Antihypertensives (alpha-blockers, beta-blockers, reserpine)	Depression	Aerobic training Progressive resistance training
Hypothyroidism	Thyroxine	Osteoporosis	Progressive resistance training Weight-bearing aerobic training High-velocity, high-impact loading (e.g., jumping)
Insomnia	Benzodiazepines	Impaired motor coordination, gait, and balance	Balance training
Obesity	Energy restriction	Decreased lean body mass (muscle and bone)	Progressive resistance training
Major surgery	Operative procedure Bedrest	Catabolism Muscle wasting Deconditioning	Progressive resistance training
Rheumatic diseases Immunosuppression for organ transplant Chronic obstructive pulmonary disease	Corticosteroids	Proximal myopathy Osteoporosis Visceral fat deposition Insulin resistance, hyperglycemia Increased blood pressure, hypertension	Progressive resistance training

Note: IGF-1 = insulin-like growth factor 1.

level were independently predictive of disability in a multiple regression model, explaining fully 40% of the variance. The findings of a modest contribution of aerobic capacity to disability in elders has been reported by Morey and colleagues (214) and Posner and colleagues (173) as well, although muscle power and strength measures were not assessed in these studies. Given the fact that muscle power declines more severely than muscle strength with aging (215) and given such emerging relationships of muscle power to functional status and fall risk, exercise programs targeting increased muscle power (216) are increasingly recommended (217).

Longitudinal studies are better able to determine the putative causal role of sedentariness and impairments to disability. An extensive systematic review of the literature in the community-dwelling elderly population was reported by Stuck and colleagues in 1999 (218). In the 78 longitudinal studies included, low levels of physical activity and impairments of upper and lower body strength or function were rated as among the strongest predictors of future disability in these cohorts. Two longitudinal studies have been published using data from the Cooper Clinic cohort that relate physical fitness and physical activity to functional status after 5 years. Brill and colleagues (172) reported that higher strength (upper, lower, and trunk) was independently associated with functional disability in 3658 men and women at follow-up, reducing the risk by almost one half. Aerobic capacity independently reduced risk by another 10%, consistent with other suggestions as to the relative weight of these two components of fitness as regards functional abilities when both are measured in the same sample. In the other study from this cohort, Huang and colleagues (171) reported physical fitness and activity levels in 4670 middle-aged subjects over 5 years of follow-up. There was a steep gradient of risk across categories of fitness and activity, with a 70% reduction in disability at the highest tertile of aerobic fitness, compared to the lowest in both men and women. These studies are unique in expanding the relationships observed in older and disabled populations to healthy, middle-aged persons and suggest a strong role for physical activity in the prevention of disability from middle age onward.

Recent longitudinal studies have strengthened the hypothesized causal relationship between sedentariness, functional limitations, and disability in older adults. Miller and colleagues have reported results from 5151 participants in the Longitudinal Study of Aging (169) and have shown that physical activity results in a slower progression of functional limitations, and thereby slower progression to ADL/IADL disability. Specifically, older adults who walked a mile at least once per week were significantly less likely to progress to functional limitations or disability than their sedentary counterparts over the 6 years of follow-up. In another prospective study from Finland, Hirvensalo and colleagues (145) found that physical activity lowered the risk of subsequent disability and mortality among 1109 community-dwelling older adults, counteracting the negative effect of mobility impairment.

Few investigators have examined primary prevention of disability itself via exercise in controlled trials of initially healthy adults. Kerschan and colleagues (219) reported results from 124 initially nondisabled postmenopausal women who were nonrandomly assigned to home-based exercise or control groups during a visit to an outpatient medical clinic. After 7.7 years of follow-up, there were no differences between the groups in any measures of physiology or disability. The exercise program, which included elements of balance, flexibility, strengthening, postural control, and walking, prescribed 3 days per week was carried out by only 36% of the exercise group at follow-up and was likely not robust enough to induce physiological or functional changes.

Secondary prevention of disability in adults with preexisting impairments or functional limitations has been studied somewhat more extensively, but with mixed results. Mihalko and McAuley (220) reported on 58 men and women aged 71–100 years who were residents of senior citizen or nursing homes and were randomly assigned to an 8-week moderate-intensity, supervised upper body resistance training program using dumbbells or an upper body stretching control condition. Exercisers significantly increased muscle strength by more than 50%, compared with no changes in the controls. Difficulty in performing ADLs was significantly improved in exercisers and worsened in controls over the course of the intervention, as rated by primary caregivers. Strength gains were significantly related to final ADL status, but explained only 10% of the variance. In a sample of 215 community-dwelling older adults with self-reported functional limitations, 6 months of home-based strength training with elastic bands modestly increased strength, gait stability, and measures of social role functioning (but not physical functioning) compared with untreated controls (221). In contrast to many reported studies, Westhoff and colleagues found that 10 weeks of supervised strength training using a combination of isometric contractions and dynamic exercises with elastic bands for the knee extensors improved strength by 54% and lower-extremity-related ADL score by 12% in 21 older adults with lower extremity weakness who lived in sheltered housing for elders (222). These changes were preserved at 6 months of follow-up after the intervention ended. In the largest reported randomized controlled trial of exercise and disability to date, Morris and colleagues (223) randomly allocated 468 residents of six different nursing homes into resistive exercise (using dumbbells and ankle weights), nursing rehabilitation, or control conditions. After 10 months, residents in both intervention homes had significantly less decline in ADL functioning than those in control homes, and 6-minute walk time was better maintained in the exercise home subjects compared with the other two groups of residents.

A review of studies targeting disability in disease-specific populations such as depression, cardiovascular disease, stroke, chronic lung disease, and arthritis is beyond the scope of this review, but there is evidence that exercise is beneficial in all of these conditions as a primary or ancillary treatment. The largest body of data exists for older adults with osteoarthritis, which is the most common condition related to disability in the elderly population (190). Five of the 11 randomized controlled trials reported up to 1999 demonstrated improvements in disability scores relative to controls in trials from 4 weeks to 18 months in duration. Weight-bearing functional exercises, walking, and resistance training were used in various combinations in these studies, and there is no clear indication of the superiority of one modality over another in the reduction of pain and disability from osteoarthritis. The largest trial, by Ettinger and colleagues (161) in 1997, found that 439 patients randomized to aerobic exercise or resistance training for 18 months had less pain and disability at follow-up compared with controls, who declined functionally over this period. Physiological improvements in strength or aerobic capacity were not observed in this trial, and compliance was only 50% at 18 months, suggesting that other mechanisms [such as observed interactions of knee and ankle strength, gait, and balance in osteoarthritis (192)] may have been operative in the benefits observed. O'Reilly and colleagues (191) similarly found that 6 months of daily isometric quadriceps strengthening and stepping in a home-based protocol improved strength, pain, and disability in a randomized trial of 191 men and women with knee pain aged 40–79, compared with no-treatment controls. It is likely that the disability reductions in arthritis are due to the impact of exercise on a variety of factors, including muscle strength, gait and balance, body weight, pain, comorbid disease expression, self-efficacy, and depressive symptoms, among others.

Specific Exercise Recommendations for Geriatric Patients

The first Surgeon General's Report on Physical Activity and Health (8), released in July 1996, concluded that regular sustained physical activity can substantially reduce the risk of developing or dying from heart disease, diabetes, colon cancer, and high blood pressure. This hallmark report was meant to provide impetus for Americans to establish an active and fit lifestyle. Unfortunately, as shown in Table 6, relatively few Americans engage in regular physical activity despite the widely reported benefits in both the scientific and popular media. Only about 10% of the U.S. adult population reports regular, vigorous physical activity 3 days per week. A small proportion are engaged in muscle strengthening exercise, and about 25% are completely sedentary (engaged in no physical activity).

Unfortunately, disparities exist among population groups in levels of physical activity, which further exaggerate the negative health consequences of a sedentary lifestyle. According to the 1996 Surgeon General's Report on Physical Activity and Health (8), demographic groups at highest risk for inactivity are elders, women, minorities, those with low income or educational background, and those with disabilities or chronic health conditions. So, for example, in comparison to the figures for all adults shown in Table 6, 43% of adults aged 65 and older were sedentary in 1985, as were 29% in 1991. Women in general report lower than average adult participation levels for strength training (11% vs 16%). Additionally, despite the evidence on safety even in very elderly frail individuals (53,223–225), the prevalence rate for resistive exercise is even lower among the young-old (6% at ages 65–74) and rare among the old-old (4% above age 75). As might be expected, these are the same demographic groups that both bear a large burden of disability and diseases amenable to prevention and treatment with exercise, and yet often have the least access and opportunity for health promotion efforts related to physical activity. In a random sampling of 2000 Americans subsequent to the release of the Surgeon General's report, awareness of the report and its information linking exercise to chronic disease was lower among elders, ethnic minorities, and less educated adults surveyed (226). Therefore, health care practitioners should identify and understand barriers to physical activity adoption and adherence faced by vulnerable population groups and be prepared to develop programs and tools that address these barriers. This is particularly important for the prevention and treatment of disability, as high-risk individuals are more likely to be non-Caucasian, elderly, women, and from lower socioeconomic backgrounds—the same cohort with the least access to preventive health information and activity programming.

Standard references are available that outline the specifics of the physical activity/exercise prescriptions that have been found to provide improvements in physical fitness as well as health-related benefits referred to above (1,5,8,9, 227), and such detail is beyond the scope of this review. However, these consensus statements often do not provide adequate coverage of issues relevant to the care of older adults with multiple comorbid illnesses or frailty and tend to focus primarily on cardiorespiratory fitness, which may be the least feasible mode of training for very aged or frail individuals. Therefore, an overview of additional important considerations in the exercise prescription for such individuals is needed. Table 7 provides the elements of such an exercise prescription suitable for older adults spanning a wide range of health and fitness levels. It includes balance training recommendations in addition to the more standard cardiorespiratory, resistance, and flexibility modalities of exercise. Additional detail is presented in the sections that follow.

Table 6. Prevalence of Physical Activity Among Adults in the United States

Type of Physical Activity	Percentage of Adult Americans Reporting in 1995
Light to moderate sustained physical activity for 30 minutes at least 5 days per week*	23%
Regular vigorous physical activity at least 3 days per week that promotes cardiorespiratory fitness**	16%
Sedentary lifestyle (inactive, most of time spent sitting)	23%
Stretching (one time/week)	27% (1991)
Strengthening exercises (three times/week)	16% (1991)

Note: Data are reported in the Draft Objectives of Healthy People 2010 (www.HealthyPeople.com) and are drawn from National Health Interview Survey, Centers for Disease Control, and National Center for Health Statistics sources.

*Sustained physical activity requires muscular movements and is at least equivalent to brisk walking. In addition to walking, activities may also include swimming, cycling, dancing, gardening and yardwork, and various domestic and occupational activities.

**Vigorous physical activities are rhythmic, repetitive physical activities that use large muscle groups at 60% or more of maximum heart rate for age. An exercise heart rate of 60% of maximum heart rate for age is about 50% of maximal cardiorespiratory capacity and is sufficient for cardiorespiratory conditioning. Maximum heart rate equals roughly 220 beats per minute minus age. Examples of vigorous physical activities include jogging/running, lap swimming, cycling, aerobic dancing, skating, rowing, jumping rope, cross-country skiing, hiking/backpacking, racquet sports, and competitive group sports (soccer, basketball, volleyball).

General Considerations

Because a physically active lifestyle appears to offer protection independently of its association with higher fitness levels, it may not be necessary for prevention of disease or disability to promote only those activities that would substantially modify physical capacity. For example, walking during daily life, using stairs, shifting toward more active recreational pursuits, and relying less on automated devices will decrease sedentariness and should thus confer benefit, although such experimental trials of "lifestyle" prescriptions in the elderly population have not yet been conducted. It is possible to change habitual physical activity levels in older, sedentary adults for periods up to 2 years in supervised, home-based, and long-term care settings (58,178,223), but such programs have relied upon structured resistive, balance, and aerobic exercise rather than general advice to be more active.

Modification of cardiovascular and metabolic risk factors for the purpose of disease prevention is generally associated with higher volumes and/or intensities of aerobic activities than may be achievable in frail adults, and, therefore, the extent to which this goal is relevant to the very old is not known. For example, the prevalence of type 2 diabetes is markedly reduced by increased frequency and intensity of walking and other cardiovascular forms of exercise (155, 206,228). It should be noted, however, that the effects of re-

Table 7. Exercise Recommendations for Optimal Aging and Prevention and Treatment of Disease in Older Adults

Modality	Resistance Training	Cardiovascular Endurance Training	Flexibility Training	Balance Training
Dose				
Frequency	2–3 days/wk	3–7 days/wk	1–7 days/wk	1–7 days/wk
Volume	1–3 sets of 8–12 repetitions, 8–10 major muscle groups	20–60 min per session	Major muscle groups 1 sustained stretch (20 sec) of each	1–2 sets of 4–10 different exercises emphasizing dynamic postures*
Intensity	15–17 on Borg Scale (70–80% 1RM), 10 sec/repetition, 1 min rest between sets	12–13 on Borg Scale (40–60% heart rate reserve or maximal exercise capacity)	Progressive neuromuscular facilitation technique*	Progressive difficulty as tolerated†
Requirements for safety and maximal efficacy	Slow speed, no ballistic movements, day of rest between sessions Good form, no substitution of muscles No breath holding, Valsalva manuever Increase weight progressively to maintain relative intensity If equipment available, power training (high-velocity, high-loading) provides benefits of both increased strength and power	Low-impact activity Weight-bearing if possible, include standing/walking Increase workload progressively to maintain relative intensity	Static rather than ballistic stretching	Safe environment or monitoring Dynamic rather than static modes Gradual increase in difficulty as competence is demonstrated

*Proprioceptive neuromuscular facilitation involves stretching as far as possible, then relaxing the involved muscles, then attempting to stretch further, and finally holding the maximal stretch position for at least 20 seconds.

**Examples of balance enhancing activities include T'ai Chi movements, standing yoga or ballet movements, tandem walking, standing on one leg, stepping over objects, climbing up and down steps slowly, turning, standing on heels and toes, walking on compliant surface such as foam mattresses, maintaining balance on moving vehicle such as bus or train, etc.

†Intensity is increased by decreasing the base of support (e.g., progressing from standing on two feet while holding onto the back of a chair to standing on one foot with no hand support); by decreasing other sensory input (e.g., closing eyes or standing on a foam pillow); or by perturbing the center of mass (e.g., holding a heavy object out to one side while maintaining balance, standing on one leg while lifting other leg out behind body, or leaning forward as far as possible without falling or moving feet).

sistance training on insulin sensitivity and glucose homeostasis are at least as great as those ascribed to aerobic training (113,114,229), although too few individuals practice this form of exercise to have been studied epidemiologically. Thus, resistance training may be more feasible as a preventive exercise recommendation for the older adult with insulin resistance and complex comorbidity, in whom the difficulty of implementing an aerobic exercise program may hinder compliance. General guidelines regarding specific exercise modalities appropriate for the elderly population are outlined below.

Resistance Training

The problems of mobility impairment, falls, arthritis, osteoporotic fractures, and functional status are related in part to muscle strength and mass (200,213), and thus strengthening activities, while important for all age groups, are particularly important for near-frail and frail older adults. Age-related loss of strength, muscle mass, and bone density, which is most dramatic in women, may be attenuated by strengthening exercises begun in middle or old age (9,78), and strength may be regained even long afterward with appropriate resistance training (230). Severe losses of muscle and bone mass may never be completely regenerated with exercise alone, but it may still serve as an adjunct to other therapeutic approaches.

Resistance training in older adults results in a range of clinical adaptations that are relevant to disease and disability treatment. Gains in strength after resistance training in frail elders may be accompanied by improvements in other physiological impairments [balance (78), aerobic capacity (231,232), flexibility (233,234)], as well as performance-based tests of functional limitations such as gait velocity, ability to rise from a chair, and stair climbing power (53,224,230,235–237). Self-reported disability has been assessed far less frequently, but has been seen to improve, particularly in specific populations, such as those with osteoarthritis of the knee, for example (161,191). Psychological responses to resistance training include improved morale, depressive symptoms, and self-efficacy (129,137,238, 239), and these factors have strong independent effects on functional status as well (211).

Low-moderate intensity resistance training programs have been increasingly advocated for elders, particularly the frail or disabled, as a way to increase the practical dissemination and acceptability of this modality of training. Most programs utilize free weights such as dumbbells and ankle cuff weights or elastic bands and body weight as the means of resistance. Although it is possible to demonstrate significant strength gains with such interventions, in fact, most programs do not change strength substantially when it is objectively measured (161,223,237). This does not mean that this type of exercise is not beneficial, however, as it has been shown to reduce disability (223), improve gait stability (240), reduce injurious fall rates (177–179), and reduce arthritis pain and disability (161), for example. Given that the physiological changes are subtle or nonexistent with low-intensity resistance training, this is unlikely to be the primary mechanism of action behind the changes in disability or other outcomes observed in these trials. It is possible that improvements in other domains such as self-efficacy may be operative here, but many gaps in knowledge still exist. Until more is known, intensities that have been shown to benefit specific conditions should be utilized when possible when they serve as primary treatment. For example, high-intensity, progressive resistance training or aerobic training reduces depression to a similar extent as pharmacological intervention (130,135) in patients with major depression, whereas low-intensity exercise of either modality is far less effective (136,241). More research is required to define the appropriate intensities and dosages of resistive exercise for other conditions so that cost-effective methods can be developed for implementation into clinical practice.

Aerobic Exercise

Healthy older adults adapt to moderate to high-intensity cardiovascular training similarly to younger adults (9), and most health outcomes appear to be achievable with moderate levels of exercise (approximately 60% of heart rate reserve or maximal exercise capacity). High-intensity aerobic training interventions have not been described in frail elderly populations. Low- to moderate-intensity aerobic activities such as walking, standing, and stationary cycling at 60% of maximal predicted heart rate have been associated with modest improvements in cardiovascular efficiency (242,243) and mobility tasks (244) (walking, standing from a chair, etc.). It should be noted, however, that the energy cost of activities for frail elders with assistive devices such as walkers and wheelchairs, joint deformities, and gait disorders may be significantly higher than standard equations would predict, and, therefore, until studies using indirect calorimetry to both monitor effort as well as document change are reported in this population, the exact magnitude of the physiologic benefits of aerobic training remain unclear. It is likely, however, that as in younger adults, lower intensity aerobic activities may provide benefits in terms of quality of life, psychological outcomes, and relief of pain and disability, without changing cardiovascular conditioning substantively.

The use of aerobic training in disabled adults should be delayed until balance and strength have been addressed with specific exercise prescriptions. If this is not done, mobility will be severely limited by the impairments of neuromuscular function, and aerobic training will be difficult or even hazardous to prescribe in any case. A meta-analysis of the various exercise studies in the FICSIT trials indicates a small protective effect of exercise, although the interventions, which included only aerobic training (walking), were not protective (245). This is in agreement with other walking studies in the elderly population that in general do not show a balance-enhancing effect. A simple rule is to watch the person rise from a chair, stand with eyes closed, open eyes, and then walk across the room. If standing from the chair is difficult, or requires use of the arms, strengthening exercise should be prescribed first. If standing balance is impaired, balance exercises are also indicated. Only if these first two tests are performed easily should aerobic training be the first mode of exercise prescribed.

Balance Training

Exercise programs that include balance training or resistive exercises have been shown to improve clinical testing of balance in elders selected for mobility disorders or functional impairment. In the healthy elderly, T'ai Chi has been shown to reduce fall rates (246), and a multicomponent intervention that included low-intensity lower extremity resistive exercises and balance training also significantly reduced falls (247). A combination of balance and strengthening exercises in the home setting has been shown to reduce falls and injuries, particularly in women over the age of 80 (177–179), but the independent contribution of balance exercises to this outcome is not known. Balance training has not been shown, as an isolated intervention in frail elders, to have a direct impact on functional status, although it may improve the balance impairment (63). In the long-term care setting, T'ai Chi has been more difficult to implement and has not been shown to reduce fall rates (216). There is still much debate about the exact nature of the stimulus or dose of balance training required to best enhance balance and ultimately reduce falls (248), although most programs described use some combination of the techniques outlined in Table 7.

Flexibility Exercise

Flexibility declines markedly with aging and is associated with disability (211,249–251), but no specific studies have been done to test responsiveness to standard proprioceptive neural facilitation or other techniques in this population (252). Increases in active range of motion involving trained muscle groups have been observed following high-intensity progressive resistance training in frail elders (53), depressed elders (233), and cardiac rehabilitation patients (234), but not after low-intensity resistance training (233) or most aerobic interventions. It is likely that bone deformity as well as muscle weakness, tendon shortening, and tissue inelasticity from disuse contribute to the problem, thus indicating more than one approach may be needed for its resolution.

There is no evidence that training for flexibility or physical therapy programs concentrating on range of motion and stretching alone have a significant impact on disability (253). Due to misconceptions about the efficacy and safety of other modes of exercise, however, stretching is often the only exercise prescribed for disabled or frail elders. The data reviewed above on the safety and efficacy of resistance training and balance training in particular would argue for the substitution of these exercise modalities, whenever possible, as an alternative to some of the "movement programs" offered in aged care facilities and other settings.

The contraindications to exercise in this population are not different from those applicable to younger healthier adults (254). In general, frailty or extreme age is not a contraindication to exercise, although the specific modalities may be altered to accommodate individual disabilities (243). Acute illnesses, particularly febrile illnesses, undiagnosed or unstable chest pain, uncontrolled diabetes, hypertension, asthma, congestive heart failure, or new or undiagnosed musculoskeletal pain, weight loss, or falling episodes, warrant investigation, regardless of exercise status, but certainly before a new regimen is begun. Temporary avoidance of certain kinds of exercise is required during treatment of hernias, foot ulcers, cataracts, retinopathy, or joint injuries, for example. A very small number of untreatable or serious conditions are more permanent exclusions for vigorous exercise, including an inoperable enlarging aortic aneurysm, known cerebral aneurysm, malignant ventricular arrhythmia, critical aortic stenosis, end-stage congestive heart failure or other rapidly terminal illness, or severe behavioral agitation in response to participation in exercise secondary to dementia, alcoholism, or neuropsychological illness. It should be noted, however, that the mere presence of cardiovascular disease, diabetes, stroke, osteoporosis, depression, dementia, chronic pulmonary disease, chronic renal failure, peripheral vascular disease, or arthritis is not by itself a contraindication to exercise. In fact, for many of these conditions, exercise will offer benefits not achievable through medication alone. The intolerance to many medication side effects in the very old makes the search for alternative nonpharmacological therapies, such as exercise, very attractive in this cohort.

The literature on exercise training in the frail elderly population in nursing homes, between the ages of 80 and 100, includes no reports to date of serious cardiovascular incidents, sudden death, myocardial infarction, exacerbation of metabolic control of diabetes, or hypertension (53,223–225,235,236,243, 244,253,255–264). Thus, a considerable body of data now exists to demonstrate the safety of initiating exercise in these settings in cohorts with multiple comorbidities and preexisting functional impairment and disability.

A "lifestyle" approach to health promotion with exercise has been recently advocated in an attempt to improve the penetration of public health messages about exercise (265). It is not clear that such an approach is superior to a structured exercise prescription nor that it would work for elderly individuals who may have less opportunity to integrate physical activity into work or leisure-time activities. However, it may be prudent to offer both structured exercise recommendations (see Table 7) as well as suggestions on incorporating these elements into everyday activities, in order to maximize compliance with the prescription.

Summary and Directions for Future Research

There are sufficient data from both epidemiological studies and experimental trials to warrant the training of all physicians, including geriatricians, in the basics of exercise prescription for health-related and quality-of-life benefits. Unfortunately, recent surveys indicate that physicians are less likely to offer advice to exercise to older adults or those who are not contemplating an increase in physical activity, despite the evidence of marked health benefits for such patients (266). Screening for sedentariness should take place at all major encounters with health care professionals, given its role as a potent risk factor for all-cause and cardiovascular mortality, obesity, hypertension, insulin resistance, cardiovascular disease, diabetes, stroke, colon cancer, depression, osteoporosis, recurrent falls, and disability, among other conditions. Exercise recommendations should be integrated into the mainstream of other health care recommendations, rather than being a separate entity. This is particularly important when they serve as adjunctive treatment for diseases or are meant to counteract specific side effects of standard therapy. Exercise advice should be specific in terms of modality, frequency, duration, and intensity, and accompanied by practical implementation solutions and behavioral support systems for monitoring progress and providing feedback.

The wealth of epidemiological data linking physical activity to health status and optimal aging is not yet matched by a similar quantity and quality of experimental evidence of benefit derived from randomized controlled trials. There is still need for scientifically rigorous research in those older than 75, as well as large, long-term prospective studies with disease and disability as primary outcomes. In addition, investigations that better define the dose–response relationships between physical activity participation, physical fitness, and major chronic diseases and their risk factors, the mechanisms of exercise effects on health status, strategies for health behavior change, and the cost-effectiveness and overall risk-benefit of exercise implementation would contribute significantly to knowledge in this field.

Knowledge of benefit, however well-substantiated, may be necessary, but is not sufficient to change either physician-prescribing habits or the likelihood of adoption and long-term adherence on the part of patients. Given that sedentariness is far more common than regular participation in appropriate levels and modes of physical activity (267), attention to the demographic, health status, and societal influences on exercise behavior and how to change it is needed as well. Ultimately, the penetration of these recommendations into the most inactive cohorts in the community, who have the most to gain from increases in levels of physical activity and fitness (143,268), will depend on a combination of evidence-based guidelines coupled with health professional training and behavioral programs tailored to age-specific barriers and motivational factors (265,269,270).

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