REVIEW ARTICLE
Journal of Gerontology: MEDICAL SCIENCES
2001, Vol. 56A, No. 7, M412–M423

Have We Oversold the Benefit of Late-Life Exercise?

Julie J. Keysor and Alan M. Jette

Sargent College of Health and Rehabilitation Sciences, Boston University, Massachusetts.

Background. Increasing exercise among older adults to improve function and prevent or decrease disability is widely promoted in developed countries. This review seeks to critically evaluate the degree to which existing scientific evidence supports these claims.

Methods. A literature review was performed in Medline and Best Evidence databases for the years 1985 to 2000. Experimental and quasi-experimental aerobic and resistance exercise interventions were reviewed for impairment, function, and disability outcomes. The impact of exercise on specific impairments, functions, and disabilities was examined by summarizing the findings reported across all studies.

Results. Thirty-one studies were identified. Impairment and functional outcomes were reported in 97% and 81% of the studies, respectively; half of the studies examined disability outcomes. The most consistent positive effects of late-life exercise were observed in strength, aerobic capacity, flexibility, walking, and standing balance, with over half of the studies that examined these outcomes finding positive effects. Of the studies that examined physical, social, emotional, or overall disability outcomes, most found no improvements. In the five studies that reported reduced physical disability, the effect sizes ranged from .23 to .88.

Conclusions. Late-life exercise clearly improves strength, aerobic capacity, flexibility, and physical function. Existing scientific evidence, however, does not support a strong argument for late-life exercise as an effective means of reducing disability. This may be due, in part, to methodological limitations in studies that have examined disability outcomes. On the other hand, the theoretical basis of interventions aimed at reducing disability may need to extend beyond exercise and address behavioral and social factors.

A strong link between exercise and improved health and well-being is widely accepted for individuals of all ages. In the older adult, exercise is known to reduce the risk of premature mortality in general (1–4) and of coronary heart disease, hypertension, colon cancer, and diabetes mellitus in particular (5–10). Exercise has been shown to be important for the health of muscles, bones, and joints, which is believed to be a major determinant of loss of function in late life (11,12). The accumulation of scientific evidence led to the now landmark 1996 U.S. Surgeon General's recommendation that people of all ages include a minimum of 30 minutes of physical activity of moderate intensity (such as brisk walking) on most, if not all, days of the week (13). This report acknowledges that, for most people, greater health benefits can be obtained by engaging in physical activity of more vigorous intensity or of longer duration.

Whereas ample scientific evidence has accumulated on the positive effects of exercise on disease prevention, muscle strength, flexibility, and cardiovascular fitness in adults of all ages, it remains less clear as to the full range of functional benefits of exercise for the sedentary, deconditioned, and/or impaired, older adult. As the 1996 Surgeon General's report notes, whereas physical activity appears to improve physical functioning in persons compromised by poor health, the scientific evidence supporting this claim is less clear (14). Yet, increasing physical activity and/or formal exercise by the sedentary older population in the United States is widely promoted in the public health community as an effective means of improving physical function and reducing or preventing disability in late life (15,16). Does the existing scientific evidence actually support the wide scope of positive claims, or have the public health recommendations extended beyond current scientific evidence? This review seeks to critically evaluate the existing scientific evidence on the wide range of purported functional benefits of exercise when performed by the older adult. More specifically, we examine the degree to which the scientific literature directly supports the assertion that exercise enhances the older adult's physical function, prevents the onset of disability, and/or restores daily activities that are already compromised in older adults. We examine if exercise is an effective means of preventing or reducing disability and a feasible means of promoting independence in late life.

To evaluate the accumulated scientific literature on the degree to which exercise is an established means of enhancing physical function and/or improving disability in late life, outcome measures must be organized around some conceptual framework. We have chosen to structure this review around a hierarchy of outcomes using Nagi's disablement model (17,18), which has been widely used in the gerontologic literature. We examined the effects of exercise on measures of muscle strength, range of motion or flexibility, maximum oxygen uptake, body composition, and neuromuscular control, all examples of effects on physical impairments. Improvements of exercise on functional limitations were demonstrated by evaluating the effects of exercise on measures of gait function, chair transfers, stair climbing, general mobility skills, weighted-lift task, and/or standing balance. Finally, we evaluated the direct impact of exercise on disabilities as reflected in the individual's behavior across a range of activities of daily living (ADLs) and social activities. Following our review of the existing scientific evidence on the benefits of exercise in late life, we discuss several recommendations for future research on optimizing late-life physical function and ability.

Methods

Medline and the Best Evidence databases were searched for experimental or quasi-experimental studies of late-life exercise. The terms "exercise" and "physical activity" were used to capture studies related to exercise; the terms "clinical trials," "randomized controlled trials," and "quasi-experimental" were used to capture experimental and quasi-experimental study designs. The search was limited to studies published in English between 1985 and 2000 that included an examination of the impact of aerobic and strengthening exercise on functional activities and/or disabilities among older adults. We excluded studies that reported solely impairment-level outcomes because our main objective was to examine the effects of exercise on functional limitations and disability. We also excluded studies that examined the impact of exercise among elderly persons with specific conditions such as Parkinson's Disease, chronic obstructive pulmonary disease, osteoporosis, and chronic low-back pain. We did, however, include studies that examined the effects of late-life exercise among people with arthritis because arthritis is the most prevalent chronic musculoskeletal condition among adults 65 years of age or older (19,20). Furthermore, to be included in our review, studies must have clearly identified a control group that was either waitlisted or received health education sessions, range of motion exercise, recreational activity, social visits, or a similar placebo treatment.

Of the studies meeting our criteria, we reviewed each article for (i) type of intervention program, (ii) length of intervention and follow-up assessment, (iii) sample size, and (iv) the intervention effects on impairment, function, and physical, social, emotional, and overall disability. Impairment outcomes included strength (e.g., isokinetic dynamometry, hand held dynamometry, strain gauge load cell, and single repetition maximal lift), range of motion or flexibility (e.g., goniometry measurements and sit and reach tests), aerobic capacity (e.g., blood pressure, heart rate, and maximum oxygen uptake), body composition (e.g., weight and muscle mass), and symptoms. Functional outcomes included walking (e.g., endurance, distance, speed, and gait characteristics), chair rise (e.g., sit-to-stand transfers with or without a short walk and repeated chair stands), weighted lift task (e.g., lift and place a weighted object and repeated lifts of a weighted object), general mobility skills (e.g., mobility assessments, obstacle courses, complex stand-to-floor movements), stair climbing, and balance (standing unilateral or bilateral balance tests, functional reach tests, or walking on balance beams).

To capture the multi-domain nature of disability, we examined the outcomes associated with exercise in four areas: (i) physical disability, (ii) social disability, (iii) emotional disability, and (iv) overall disability. Assessments of physical disability included the physical disability subscales of the Sickness Impact Profile (SIP) (21,22), Short-Form-36 Health Survey (SF-36) (23), the Arthritis Impact Measurement Scale (24,25), and other assessments of ADLs and/or instrumental activities of daily living (IADLs), such as the Barthel Index (26). The SF-36 social role subscale was used to examine social disability outcomes. Assessments of emotional disability included instruments tapping depressive or anxiety symptoms and affect, such as the Center for Epidemiological Studies-Depression Scale (27), the Geriatric Depression Scale (28), the SF-36 emotional subscale (23), the Philadelphia Geriatric Center Morale Scale (29), the Affect Balance Scale (30), the State-Trait Anxiety Inventory (31), and the Profile of Moods (32). Overall disability was assessed by using measures that capture summary scores of physical, social, and emotional disability, such as the SF-36 and SIP. Finally, for the studies that reported significant effects of exercise on physical disability, we report effect sizes. Effect sizes for emotional, social, and overall disability were not calculated because either few studies explored these outcomes (i.e., social and overall disability) or the outcome measures used were inconsistent (i.e., emotional disability).

Results

Thirty-one studies met our criteria—29 randomized control trials and 2 quasi-experimental (Appendix). Sample sizes ranged from 24 to 439 subjects. In most of the studies, participants were eligible if they were at least 60 years of age. A few of the studies (33–36), however, included subjects who were younger, although the mean age of the samples in all studies was over 60 years. Residential characteristics varied among the studies, with studies enrolling adults living in the community or adults residing in nursing or rest homes. The health status of participants also varied, with some studies targeting adults with functional limitations and disabilities and others targeting elderly adults without functional limitations.

The types of exercise programs fell into five categories: (i) flexibility interventions including yoga and stretching, (ii) strengthening or resistance training, (iii) aerobic conditioning (e.g., aquatic programs, low-impact aerobics, walking, or cycling), (iv) balance programs (Tai Chi or computerized balance systems), and (v) a combination of programs. Furthermore, the delivery of the programs varied, with some programs implemented in participants' homes or communities and others delivered in a supervised class format. The frequency and duration of exercise programs varied; however, in general, exercise sessions lasted 45 to 60 minutes and were performed two to three times per week. The durations of the interventions ranged from 2 to 18 months, with most interventions lasting 2 to 3 months. The length of follow-up ranged from immediate post-intervention to 9 months.

Exercise Effects on Impairment, Functional Limitation, and Disability Outcomes

In most of the studies, impairment and functional outcomes were reported. Ninety-seven percent of the studies examined the effects of exercise on at least one impairment-level factor. Eighty-one percent of the studies examined the effects of exercise on at least one functional activity-related factor. Disabilities were the least assessed outcome, with half of the studies reporting exercise effects on physical, social, emotional, or overall disability.

The most consistent beneficial exercise effect was found in strength, aerobic capacity, and range of motion or flexibility (Table 1). Of the studies in which strength effects were assessed, 88% of the studies showed that subjects who exercised achieved improved strength over control subjects. Similar findings occurred with aerobic conditioning outcomes: 70% of the studies reported that intervention subjects improved their aerobic capacity. Of the studies in which range of motion effects were examined, 63% of the studies found that exercise subjects improved range of motion or flexibility compared with control subjects. Exercise effects on body composition, neuromuscular control, and symptoms were examined in only a few studies, and the findings were inconsistent.

Walking (endurance, speed, distance, or gait), balance (static or dynamic standing), and chair rise (sit-to-stand transfers with or without a short walk or repeated stands) were the most frequently examined functional outcomes (68%, 42%, and 32%, respectively) (Table 2). Exercise effects on walking were examined in 21 studies, with 67% of the studies reporting that exercise subjects improved in walking compared with controls. Five out of 10 studies that examined the effects of exercise on chair rise reported improvements among exercise subjects; 8 of 13 studies reported improvements in balance among exercise participants. The other functional performance items were assessed less frequently.

The effects of exercise on physical, social, emotional, and overall disability were less clear (Table 3). Approximately half of the studies examined physical disability as an outcome, 35% examined some aspect of emotional disability, 13% examined social disability, and only 3% examined overall disability. Of the studies that examined whether exercise decreased physical disability, only five studies (36%) found significant improvements among exercise participants. Beneficial effects of exercise on some aspect of emotional disability were reported in 36% of the studies. Of the four studies that examined whether exercise improved social role performance, only one study found significant improvements. Overall disability (i.e., a summary of physical, social, and emotional disability) was reported in one study, with exercise subjects reporting improvement in overall disability.

Magnitude of the Impact of Late-Life Exercise on Physical Disability

As the data in Table 4 reveal, the magnitude of the impact of exercise on physical disability was quite varied. With the exception of studies by Kovar and colleagues (34) and Mueleman and colleagues (37), the impact of the intervention programs was small to modest. Jette and colleagues (38), Minor and colleagues (33), and Ettinger and colleagues (39) found similarly modest impacts on physical disability with effect sizes ranging from .26 to .58. Mueleman and colleagues (37) showed a large positive effect of

Table 1. The Effects of Exercise on Impairments

Study	Strength*	Range of Motion/Flexibility	Aerobic Capacity	Body Composition	Neuromuscular Control	Symptoms
Ades and colleagues (57)	+		0	0		
Blumenthal and colleagues (58)	0		+	+	0	
Bravo and colleagues (35)		+			0	
Buchner and colleagues (59)	+		+			
Chandler and colleagues (42)	+					
Cress and colleagues (50)	+	+	+		0	
Damush and colleagues (36)	+					
Emery and Gatz (48)		0	0			
Ettinger and colleagues (39)	+		+			+ (pain decreased)
Fiatarone and colleagues (60)	+			+		
Jette and colleagues (61)	+					
Jette and colleagues (38)	+					
Judge and colleagues (62)	+					
Judge and colleagues (63)	+					
King and colleagues (46)		+	+			0
Kovar and colleagues (34)						+ (pain decreased)
Krebs and colleagues (64)†	+					
Lazowski and colleagues (65)	+	+				
Lord and colleagues (66)	+				+	
Lord and colleagues (67)	+					
McMurdo and Burnett (49)	0	+	0	0		
McMurdo and Johnston (43)	0	0				
Meuleman and colleagues (37)	+		+			
Minor and colleagues (33)	+	0	+			0
Rooks and colleagues (68)	+					
Rubenstein and colleagues (45)	+					
Sharpe and colleagues (69)	+				0	
Sherrington and colleagues (70)	+					
Skelton and colleagues (71)	+			0		
Stewart and colleagues (44)						
Wolfson and colleagues (72)‡	+					
Total (31 studies)	23/26	5/8	7/10	2/5	1/5	2/4

Note: + = significant beneficial effect of exercise intervention; 0 = no effect or control group improved.
*Strength includes repeated lift-weight assessments.
†Data from Jette and colleagues (38).
‡Data from Judge and colleagues (63).

Table 2. Effect of Exercise on Functional Limitations

Study	Walking (Endurance, Speed, Distance, and Gait)	Chair Rise With/Without a Short Walk	General Mobility Skills	Stair Climbing	Weighted Lift Task	Balance
Ades and colleagues (57)	+					
Blumenthal and colleagues (58)						
Bravo and colleagues (35)	+	+			+	
Buchner and colleagues (59)	0			0		0
Chandler and colleagues (42)	+	+	+			0
Cress and colleagues (50)	0		+			+
Damush and colleagues (36)						
Emery and Gatz (48)						
Ettinger and colleagues (39)	+	+		+	+	
Fiatarone and colleagues (60)	+			+		
Jette and colleagues (61)						
Jette and colleagues (38)		+				+
Judge and colleagues (62)	+					
Judge and colleagues (63)	0	0				
King and colleagues (46)	+	0			+	
Kovar and colleagues (34)	+					
Krebs and colleagues (64)*	+					
Lazowski and colleagues (65)	0	+		0		+
Lord and colleagues (66)						+
Lord and colleagues (67)	+					+
McMurdo and Burnett (49)						
McMurdo and Johnston (43)		0				
Meuleman and colleagues (37)	0					
Minor and colleagues (33)	+					
Rooks and colleagues (68)				+		+
Rubenstein and colleagues (45)	+	0	0			0
Sharpe and colleagues (69)	+					+
Sherrington and colleagues (70)	+					0
Skelton and colleagues (71)	0	0		0	0	0
Stewart and colleagues (44)						
Wolfson and colleagues (72)†	0					+
Total (31 studies)	14/21	5/10	2/3	3/6	3/4	8/13

Note: + = significant beneficial effect of exercise intervention; 0 = no effect or control group improved.
*Data from Jette and colleagues (38).
†Data from Judge and colleagues (63).

exercise on physical disability only for those members of the sample stratified into a high disability group. The largest impact was found in Kovar and colleagues' study (34) (effect size .88) of adults with osteoarthritis.

Discussion

In this review of 31 experimental or quasi-experimental exercise intervention studies, we found consistent scientific evidence that older adults who engaged in strengthening and aerobic exercise were able to increase their strength, flexibility, and aerobic capacity and improve their balance, walking, and transfer activities. These findings, along with similar findings reported by others (12,40,41), provide clear and convincing confirmation that late-life exercise has important benefits on physiological parameters as well as on basic physical function. Evidence of the beneficial effects of late-life exercise on disability outcomes, however, is less clear. This conclusion may be due in part to the small number of intervention studies that have included distinct measures of disability as outcomes compared with those that have studied impairments and functional limitations; hence, we have less literature on which to base a finding from this review. Nonetheless, of the studies we found that did examine disability outcomes, the findings are inconsistent, thus making it difficult to draw clear conclusions as to the effects of exercise in late-life on disability outcomes. Whereas most studies that examined disability outcomes did not find a beneficial effect of exercise, some studies found small to moderate effects, particularly with respect to physical disability. Existing scientific evidence does not support a strong argument for late-life exercise as an effective means of reducing disability, a finding that is supported by Chandler and Hadley (41).

Several potential methodological explanations can be offered to account for the lack of clear evidence of the positive effects of exercise on disability outcomes. These include variations in sample characteristics, differences in the type and length of the exercise intervention, inadequate sample size and power, and shortcomings in the measures of disability used by investigators.

The samples used in the five studies that reported improvements in disability with exercise consisted mainly of older adults with preexisting functional limitations, measurable physical disability (37–39), or chronic arthritis, which is a major risk factor for physical disability (33,34). Therefore, it might be reasoned that the beneficial effects of strengthening and aerobic exercises on disability outcomes might only be observed among elderly subjects with existing functional deficits where the potential for measurable improve-

Table 3. The Effect of Exercise on Disability

Study	Physical Disability	Social Disability	Emotional Disability	Overall Disability
Ades and colleagues (57)				
Blumenthal and colleagues (58)			+	
Bravo and colleagues (35)				
Buchner and colleagues (59)	0			
Chandler and colleagues (42)	0			
Cress and colleagues (50)	0	0	0	
Damush and colleagues (36)	0		0	
Emery and Gatz (48)			0	
Ettinger and colleagues (39)	+			
Fiatarone and colleagues (60)				
Jette and colleagues (61)	0	+ (older participants)	+ (men)	
Jette and colleagues (38)	+		0	+
Judge and colleagues (62)				
Judge and colleagues (63)				
King and colleagues (46)	0		0	
Kovar and colleagues (34)	+			
Krebs and colleagues (64)[†]				
Lazowski and colleagues (65)				
Lord and colleagues (66)				
Lord and colleagues (67)				
McMurdo and Burnett (49)			0	
McMurdo and Johnston (43)	0		0	
Meuleman and colleagues (37)	+			
Minor and colleagues (33)	+	0	+	
Rooks and colleagues (68)				
Rubenstein and colleagues (45)	0			
Sharpe and colleagues (69)				
Sherrington and colleagues (70)				
Skelton and colleagues (71)				
Stewart and colleagues (44)	0	0	+	
Wolfson and colleagues (72)[‡]				
Total (31 studies)	5/14	1/4	4/11	1/1

Note: + = significant beneficial effect of exercise intervention; 0 = no effect or control group improved.
*Data from Jette and colleagues (38).
[†]Data from Judge and colleagues (63).

ment in disability levels existed, as suggested by Chandler and colleagues (42). On the other hand, such an explanation would not account for the several well-conducted studies in our review with samples of older adults with functional limitations and/or disabilities that found no improvements in physical disability (42–45). Another possible explanation of the findings may be that adults who have disability caused by chronic arthritis respond particularly well to exercise interventions: three of the five studies that found beneficial impacts of exercise on function and disability used a sample of people with arthritis.

The type and duration of the exercise intervention might also account for some of the paucity of positive effects of late-life exercise on disability outcomes. Generally, the interventions employed in the studies we reviewed consisted of standard exercise programs performed at least two to three times per week for a relatively short period of 8 to 12 weeks. Interventions of longer duration may be required to translate changes in impairments and functional limitations into change in the daily life activities of older adults. Whereas 8 to 12 weeks may be sufficient to demonstrate physiological and functional improvement, it may take longer to achieve measurable behavioral change. In this vein, it is interesting to note the extended duration of the Ettinger and colleagues (39) study in which physical disability improvements were achieved in subjects with chronic arthritis. In the Ettinger intervention, the longest intervention period of all the studies we reviewed, the first 12 weeks of the program consisted of a group exercise program with a final 15 months of the intervention involving a home-based program with occasional contact by health professionals to address questions, progress the training program, and encourage participation. Beneficial effects of exercise were reported at the completion of the study (i.e., after the 18-month intervention). Whereas it may be that longer intervention durations are desirable to best capture beneficial improvements in disability, it is clear that they are not required to demonstrate behavioral improvements. In the other four studies that we reviewed, the duration of the exercise programs that achieved disability improvements (33,34,37,38) ranged from 2 to 6 months, similar in duration to most of the studies that did not achieve behavioral change. Furthermore, no improvements in disability were found in the study by King and colleagues (46), which included a 12-month intervention period.

With respect to the type of intervention studied, most studies used standard exercise programs performed by participants engaging in individual and/or group strength training or aerobic exercise routines. There were some exceptions, however, where the intervention program included structured cognitive/behavioral components designed to maximize exer-

Table 4. Effect Size of Selected Studies Reporting Significant Improvements in Physical Disability

Study	n*	Effect Size	Mean Difference	Pooled Standard Deviation
Ettinger and colleagues (39)				
Basic ADLs	293	.28	0.10	0.36
Complex ADLs	293	.23	0.14	0.61
Minor and colleagues (33)				
Aquatic exercise vs control	68	.54	1.2	2.24
Walking exercise vs control	56	.58	1.3	2.25
Jette and colleagues (38)				
Physical disability 3-mo follow-up	215	.30	0.28	0.93
Physical disability 6-mo follow-up	215	.26	0.24	0.93
Kovar and colleagues (34)	92	.88	2.22	2.51
Mueleman and colleagues (37)				
Most dysfunctional group (score <13 on disability scale)†	33	.74	2.7	3.65
More functional group (score ≥13 on disability scale)†	25	−.21	−0.5	2.41

Note: ADL = activity of daily living.

*n = subjects from the intervention and control groups at follow-up assessment.

†Combined physical ADL and instrumental ADL scales with scores ranging from 0 to 26.

cise adherence and maintain behavioral change among the participants. Jette and colleagues (38), for example, used a social-cognitive theoretically driven intervention to increase exercise adoption and enhance adherence change over a 6-month intervention period. A physical therapist delivered the exercise intervention in the subjects' homes where specific cognitive and behavioral strategies were employed to enhance subjects' attitudes toward exercise. Therapists used ongoing behavioral incentives and subsequent telephone contacts during the 6-month intervention to help subjects progress and maintain their exercise program. Similarly, Kovar and colleagues' (34) intervention was theoretically based to enhance exercise adherence. The combination of exercise intervention plus a behavioral science component may have resulted in cognitive and behavioral changes among participants that, in turn, enhanced the impact of the exercise intervention on disability behavior (47). On the other hand, King and colleagues (46) also used a theoretically driven intervention and found no improvements in physical disability.

An inadequate sample size, in part, might explain some of the lack of impact of exercise on disability outcomes. Several of the studies that examined disability outcomes had small sample sizes, which may have resulted in inadequate statistical power for finding significant disability effects (36,43,45,48–50). Disability outcome "trends" may have been significant if more subjects were included in the study; thus the beneficial effects of exercise reported in this review may be underestimated. Four of the five studies that reported significant improvements in physical disability included samples of 100 participants or more. The studies by Ettinger and colleagues (39) and Jette and colleagues (38), for example, had larger samples compared to most studies included in this review.

A final methodological reason for the disability findings in this review may be inadequacies in the disability outcome measures used in these clinical trials. Physical disability was the outcome examined most frequently, and the instruments used assessed ADL and/or IADL abilities. The lack of responsiveness of existing disability measures to detect important changes resulting from ceiling or floor effects, however, is a shortcoming of these measurements that limits the thorough evaluation of interventions directed toward reducing disability. These effects occur if the instrument content lacks sufficient breadth or if the increments of item ratings are too global. Whereas more responsive measurements of disability might have resulted in more consistent findings, our present measures are somewhat limited in this capacity because they were not designed primarily for use in controlled trials. For effective use in trials such as those we reviewed, there exists an ongoing need for disability instruments to be developed with the explicit purpose of detecting change (51,52).

In addition to the methodological explanations discussed above, another reason for the inconsistent findings on the relationship between exercise and disability might be an oversimplified theoretical rationale for the hypothesized impact of late-life exercise on the severity of disability. The disablement model provides a framework for examining the rationale behind exercise interventions designed to have an impact on physical disability. The disablement model posits that the main pathway by which chronic disease or pathology leads to subsequent physical disability is through its impact on intervening impairments and functional limitations. We can use a simple clinical example to illustrate the disablement process linking a chronic pathology with subsequent disability. A woman aged 75 with osteoarthritis (pathology) may have a weak grip and restricted finger range of motion (musculoskeletal impairments). These impairments may cause difficulty in grasping and holding objects (a functional limitation), which leads to difficulty or restriction in getting dressed and cooking her meals (physical disabilities). From a disablement model perspective, an exercise intervention designed to improve this woman's dressing and cooking disability would achieve its impact by reducing her musculoskeletal impairments and functional limitations. Improvements in these areas would be hypothesized to reduce the difficulty she experienced in performing ADLs and IADLs.

Many have criticized the main pathways of the original disablement process as overly medical and too simplistic, which has led to modifications of Nagi's original formulation taking into account the psycho-social and medical aspects of disability in late life (18,53,54). A sociomedical model of disablement may be useful in designing interventions beyond exercise that might be more effective in decreasing late-life disability. The progression from initial pathology to impairment to functional limitation, although viewed as a necessary pathway to disability, may not be sufficient to result in subsequent disability or its reduction. Interventions designed to reduce disability may need to look beyond the main disablement pathways. Broader personal risk factors, such as beliefs, emotions, social norms, coping strategies, and even demographic background, might be important predisposing factors that may have an impact on the process of becoming disabled. In other words, the impact of pathology, impairment, and functional limitations might be mediated by an individual's beliefs, emotions, and behaviors, and thus influence the disablement process. Furthermore, the older individual faced with underlying pathology, impairments, and loss of function lives within a physical and social environment that can also have an impact on disability behavior.

Disability is operationalized by Nagi as the inability or limitation in performing socially defined roles expected of individuals within a social and physical environment (17) and is conceptualized as the product of the person-environment interaction—the "gap between a person's capabilities and the demands of the environment" (54, p. 81). Disability is, therefore, an interaction of an individual within his or her environment and may be viewed as a behavior; potential intervention targets need to address this interaction. Disability, therefore, may be viewed as an intricate interplay of biological factors that occur within a socio-medical context consisting of the individuals' beliefs, background, and personal behaviors as well as their physical and social context. Perhaps, in employing exercise interventions to reduce disability, effects are diminished because the intervention fails to address broader risk factors such as the individual's beliefs, emotions, coping strategies, and physical and social environments (55,56).

Viewing disability from such a socio-medical perspective suggests a need for interventions beyond or in addition to those designed to reduce impairments and limitations in function, if the ultimate aim is a reduction in disability. For example, we may need to implement specific interventions designed to reduce fear, frustration, and other emotions that may limit an older person's personal and/or social role behaviors. Other intervention targets may involve improving self-efficacy—older persons' perceptions of their ability to utilize their level of functional ability—or interventions designed to enhance readiness to change and problem-solving and coping skills, so that older persons with disabilities are able to adapt to and/or modify their environment and behaviors to optimize their participation in personal and social roles. Still other areas of intervention include enhancing the ability of social and physical environments to support and encourage elderly people in their personal and social-role participation.

If, as this review and the work of others suggests (41), resistance training and aerobic conditioning alone may have little, if any, effect on disability, then we need to be clear and not overstate the known beneficial effects of exercise. The growing literature on late-life exercise supports the notion that late-life exercise improves function. However, we need to be cognizant of the potential lack of beneficial effects of exercise on disability or at least of the lack of present scientific evidence that shows late-life exercise decreases disability.

These findings have methodological as well as theoretical implications for future research on late-life exercise and disability outcomes. If our expressed aim is to use exercise to decrease late-life disability, investigators must carefully consider the target sample, the type and duration of the exercise intervention, the statistical power needed to detect disability outcomes, and the specific disability outcomes to be targeted, and how they will be assessed to maximize the likelihood of detecting positive effects if they occur. Also, the theoretical basis of programs should be considered so that stronger, theoretically driven interventions designed to have an impact on disability may be developed and evaluated. Perhaps in addressing disability we need to target directly the person-environment interaction. Therefore, more research is needed to examine the mediating and moderating role of beliefs, emotions, coping strategies, and physical and social environments so that we can develop and evaluate interventions to enhance behavior and reduce late-life disability.

Acknowledgments

This work was supported by Grants T-32 AG 00220 and AG11669 from the National Institute on Aging and Grant H113B990005 from the National Institute on Disability and Rehabilitation Research. We thank Dr. Tim Heeren for his assistance with calculating effect sizes.

Address correspondence to Alan M. Jette, PhD, PT, Boston University, Sargent College of Health and Rehabilitation Sciences, 635 Commonwealth Avenue, Boston, MA 02215.

References

1. Lindsted KD, Tonstad S, Kuzma JW. Self-report of physical activity and patterns of mortality in Seventh-Day Adventist men. *J Clin Epidemiol.* 1991;44:355–364.
2. Paffenbarger RS Jr, Hyde RT, Wing AL, Lee IM, Jung DL, Kampert JB. The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. *N Engl J Med.* 1993; 328:538–545.
3. Paffenbarger RS Jr, Kampert JB, Lee IM, Hyde RT, Leung RW, Wing AL. Changes in physical activity and other lifeway patterns influencing longevity. *Med Sci Sports Exerc.* 1994;26:857–865.
4. Kaplan GA, Strawbridge WJ, Cohen RD, Hungerford LR. Natural history of leisure-time physical activity and its correlates: associations with mortality from all causes and cardiovascular disease over 28 years. *Am J Epidemiol.* 1996;144:793–797.
5. Berlin JA, Colditz GA. A meta-analysis of physical activity in the prevention of coronary heart disease. *Am J Epidemiol.* 1990;132:612–628.
6. Helmrich SP, Ragland DR, Leung RW, Paffenbarger RS Jr. Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus. *N Engl J Med.* 1991;325:147–152.
7. Burchfiel CM, Sharp DS, Curb JD, et al. Physical activity and incidence of diabetes: the Honolulu Heart Program. *Am J Epidemiol.* 1995;141:360–368.
8. Giovannucci E, Ascherio A, Rimm EB, Colditz GA, Stampfer MJ, Willett WC. Physical activity, obesity, and risk for colon cancer and adenoma in men. *Ann Intern Med.* 1995;122:327–334.
9. Longnecker MP, Gerhardsson le Verdier M, Frumkin H, Carpenter C. A case-control study of physical activity in relation to risk of cancer of the right colon and rectum in men. *Int J Epidemiol.* 1995;24:42–50.
10. Whaley MH, Blair SN. Epidemiology of physical activity, physical fitness and coronary heart disease. *J Cardiovasc Risk.* 1995;2:289–295.
11. Evans WJ. Exercise and nutritional needs of elderly people: effects on muscle and bone. *Gerontology.* 1998;15:15–24.
12. Layne JE, Nelson ME. The effects of progressive resistance training on bone density: a review. *Med Sci Sports Exerc.* 1999;31:25–30.
13. U.S. Department of Health and Human Services. Introduction, summary, and chapter conclusions. In: *Physical Activity and Health: A Report of the Surgeon General*. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, International Medical Publishing; 1996:3–8.
14. U.S. Department of Health and Human Services. The effects of physical activity on health and disease. In: *Physical Activity and Health: A Report of the Surgeon General*. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, International Medical Publishing; 1996:81–172.
15. Carlson JE, Ostir GV, Black SA, Markides KS, Rudkin L, Goodwin JS. Disability in older adults. 2: Physical activity as prevention. *Behav Med.* 1999;24:157–168.
16. Chiriboga DA, Ottenbacher K, Haber DA. Disability in older adults. 3: Policy implications. *Behav Med.* 1999;24:171–180.
17. Nagi SZ. Some conceptual issues in disability and rehabilitation. In: Sussman MB, ed. *Sociology and Rehabilitation*. Washington, DC: American Sociological Association; 1965.

18. Verbrugge LM, Jette AM. The disablement process. *Soc Sci Med.* 1994;38:1–14.
19. Centers for Disease Control. Arthritis prevalence and activity limitations—United States, 1990. *MMWR.* 1994;43:433–438.
20. Hughes SL, Dunlop D. The prevalence and impact of arthritis in older persons. *Arthrit Care Res.* 1995;8:257–264.
21. Bergner M, Bobbitt RA, Pollard WE, Martin DP, Gilson BS. The sickness impact profile: validation of a health status measure. *Med Care.* 1976;14:57–67.
22. Bergner M, Bobbitt RA, Carter WB, Gilson BS. The sickness impact profile: development and final revision of a health status measure. *Med Care.* 1981;19:787–805.
23. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care.* 1992;30:473–483.
24. Meenan RF, Gertman PM, Mason JH. Measuring health status in arthritis: the arthritis impact measurement scales. *Arthritis Rheum.* 1980; 23:146–152.
25. Meenan RF, Mason JH, Anderson JJ, Guccione AA, Kazis LE. AIMS2. The content and properties of a revised and expanded Arthritis Impact Measurement Scales Health Status Questionnaire. *Arthritis Rheum.* 1992;35:1–10.
26. Mahoney FI, Barthel DW. Functional evaluation: The Barthel Index. *Md State Med J.* 1965;14:61–65.
27. Radloff LS. The CES-D scale: a self-report depression scale for research in the general population. *Appl Psychol Measurement.* 1977;1:385–401.
28. Yesavage JA, Brink TL, Rose TL, et al. Development and validation of a geriatric depression screening scale: a preliminary report. *J Psychiatr Res.* 1982;17:37–49.
29. Lawton MP. The Philadelphia Geriatric Center Morale Scale: a revision. *J Gerontol.* 1975;30:85–89.
30. Bradburn NM. *The Structure of Psychological Well-being*. Chicago: Aldine; 1969.
31. Spielberger CE, Gorsuch RL, Luschene RE. *Manual for the State-Trait Anxiety Inventory*. Palo Alto: Consulting Psychologist Press; 1970.
32. McNair DM, Lorr M, Droppleman LF. *Profile of Mood States Manual*. San Diego: Edits; 1981.
33. Minor MA, Hewett JE, Webel RR, Anderson SK, Kay DR. Efficacy of physical conditioning exercise in patients with rheumatoid arthritis and osteoarthritis. *Arthritis Rheum.* 1989;32:1396–1405.
34. Kovar PA, Allegrante JP, MacKenzie CR, Peterson MG, Gutin B, Charlson ME. Supervised fitness walking in patients with osteoarthritis of the knee: a randomized, controlled trial. *Ann Intern Med.* 1992;116:529–534.
35. Bravo G, Gauthier P, Roy PM, et al. Impact of a 12-month exercise program on the physical and psychological health of osteopenic women. *J Am Geriatr Soc.* 1996;44:756–762.
36. Damush TM, Damush JG Jr. The effects of strength training on strength and health-related quality of life in older adult women. *Gerontologist.* 1999;39:705–710.
37. Meuleman JR, Brechue WF, Kubilis PS, Lowenthal DT. Exercise training in the debilitated aged: strength and functional outcomes. *Arch Phys Med Rehabil.* 2000;81:312–318.
38. Jette AM, Lachman M, Giorgetti MM, et al. Exercise—it's never too late: the strong-for-life program. *Am J Public Health.* 1999;89:66–72.
39. Ettinger WH, Burns R, Messier SP, et al. A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis: the fitness arthritis and seniors trail. *JAMA.* 1997;277:25–31.
40. Evans WJ. Effects of exercise on body composition and functional capacity of the elderly. *J Gerontol A Biol Sci Med Sci.* 1995;50(special issue):147–150.
41. Chandler JM, Hadley EC. Exercise to improve physiologic and functional performance in old age. *Clin Geriatr Med.* 1996;12:761–784.
42. Chandler JM, Duncan PW, Kochersberger G, Studenski S. Is lower extremity strength gain associated with improvement in physical performance and disability in frail, community-dwelling elders? *Arch Phys Med Rehabil.* 1998;79:24–30.
43. McMurdo ME, Johnstone R. A randomized controlled trial of a home exercise programme for elderly people with poor mobility. *Age Ageing.* 1995;24:425–428.
44. Stewart AL, Mills KM, Sepsis PG, et al. Evaluation of CHAMPS, a physical activity promotion program for older adults. *Ann Behav Med.* 1997;19:353–361.
45. Rubenstein LZ, Josephson KR, Trueblood PR, et al. Effects of a group exercise program on strength, mobility, and falls among fall-prone elderly men. *J Gerontol Med Sci*. 2000;55A:M317–M321.
46. King AC, Pruitt LA, Phillips W, Oka R, Rodenburg A, Haskell WL. Comparative effects of two physical activity programs on measured and perceived physical functioning and other health-related quality of life outcomes in older adults. *J Gerontol Med Sci.* 2000;55A:M74–M83.
47. Lachman ME, Jette AM, Tennstedt S, Howland J, Harris BA, Peterson E. A cognitive-behavioral model for promoting regular physical activity in older adults. *Psychol Health Med.* 1997;2:251–261.
48. Emery CF, Gatz M. Psychological and cognitive effects of an exercise program for community-residing older adults. *Gerontologist.* 1990;30: 184–188.
49. McMurdo MET, Burnett L. Randomized controlled trial of exercise in the elderly. *Gerontology.* 1991;38:292–298.
50. Cress ME, Buchner DM, Questad KA, Esselman PC, deLateur BJ, Schwartz RS. Exercise: effects on physical functional performance in independent older adults. *J Gerontol Med Sci.* 1999;54A:M242–M248.
51. Jaeschke R, Singer J, Guyatt GH. Measurement of health status: ascertaining the minimal clinically important difference. *Control Clin Trials.* 1989;10:407–415.
52. Liang MH. Longitudinal construct validity: establishment of clinical meaning in patient evaluative instruments. *Med Care.* 2000;38(suppl 9):II84–II90.
53. Whyte J. Enabling America: a report from the Institute of Medicine on rehabilitation science and engineering. *Arch Phys Med Rehabil.* 1998; 79:1477–1480.
54. Pope AM, Tarlov AR. A model for disability and disability prevention. In: Pope AM, Tarlov AR, eds. *Disability in America: Towards a National Agenda for Prevention*. Washington, DC: National Academy Press; 1991.
55. Jette AM. Disablement outcomes in geriatric rehabilitation. *Med Care.* 1997;35(suppl 6):JS28–JS37.
56. Stuck AE, Walthert JM, Nikolaus T, Bula CJ, Hohmann C, Beck JC. Risk factors for functional status decline in community-living elderly people: a systematic literature review. *Soc Sci Med.* 1999;48:445–469.
57. Ades PA, Ballor DL, Ashikaga T, Utton JL, Nair KS. Weight training improves walking endurance in healthy elderly persons. *Ann Intern Med.* 1996;124:568–572.
58. Blumenthal JA, Emery CF, Madden DJ, et al. Cardiovascular and behavioral effects of aerobic exercise training in healthy older men and women. *J Gerontol Med Sci.* 1989;44:M147–M157.
59. Buchner DM, Cress ME, De Lateur BJ, et al. The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. *J Gerontol Med Sci.* 1997;52A: M218–M224.
60. Fiatarone MA, O'Neill EF, Ryan ND, et al. Exercise training and nutritional supplementation for physical frailty in very elderly people. *N Engl J Med.* 1994;330:1769–1775.
61. Jette AM, Harris BA, Sleeper L, et al. A home-based exercise program for nondisabled older adults. *J Am Geriatr Soc.* 1996;44:644–649.
62. Judge JO, Underwood M, Gennosa T. Exercise to improve gait velocity in older persons. *Arch Phys Med Rehabil.* 1993;74:400–406.
63. Judge JO, Whipple RH, Wolfson LI. Effects of resistive and balance exercises on isokinetic strength in older persons. *J Am Geriatr Soc.* 1994;42:937–946.
64. Krebs DE, Jette AM, Assmann SF. Moderate exercise improves gait stability in disabled elders. *Arch Phys Med Rehabil.* 1998;79:1489–1495.
65. Lazowski DA, Ecclestone NA, Myers AM, et al. A randomized outcome evaluation of group exercise programs in long-term care institutions. *J Gerontol Med Sci.* 1999;54A:M621–M628.
66. Lord SR, Ward JA, Williams P, Strudwick M. The effect of a 12-month exercise trial on balance, strength, and falls in older women: a randomized controlled trial. *J Am Geriatr Soc.* 1995;43:1198–1206.
67. Lord SR, Lloyd DG, Nirui M, Raymond J, Williams P, Stewart RA. The effect of exercise on gait patterns in older women: a randomized controlled trial. *J Gerontol Med Sci.* 1996;51A:M64–M70.
68. Rooks DS, Kiel DP, Parsons C, Hayes WC. Self-paced resistance training and walking exercise in community-dwelling older adults: effects on neuromotor performance. *J Gerontol Med Sci.* 1997;52A:M161–M168.
69. Sharpe PA, Jackson KL, White C, et al. Effects of a one-year physical activity intervention for older adults at congregate nutrition sites. *Gerontologist.* 1997;37:208–215.
70. Sherrington C, Lord SR. Home exercise to improve strength and walk-

ing velocity after hip fracture: a randomized controlled trial. *Arch Phys Med Rehabil.* 1997;78:208–212.
71. Skelton DA, Young A, Greig CA, Malbut KE. Effects of resistance training on strength, power, and selected functional abilities of women aged 75 and older. *J Am Geriatr Soc.* 1995;43:1081–1087.
72. Wolfson L, Whipple R, Derby C, et al. Balance and strength training in older adults: intervention gains and Tai Chi maintenance. *J Am Geriatr Soc.* 1996;44:498–506.

Received January 26, 2001
Accepted January 29, 2001
Decision Editor: John E. Morley, MB, BCh

Appendix

Description and Outcome Summary of Late-Life Exercise Studies

Study	Study Design	Exercise Program	Impairment	Function	Disability
Ades and colleagues (57)	RCT (n = 24) Healthy community-dwelling elderly persons Age range: 65–79 y Mean age: 70 y	IG[†]: Strength training 3×/wk for 12 wk	Strength: PE[‡] among women Aerobic capacity: NE§ Body composition: NE	Walking: PE among men	
Blumenthal and colleagues (58)	RCT (n = 101) Community-dwelling adults without clinical manifestations of coronary disease Age range: 60–83 y Mean age: 67 y	IG1: Aerobic activity 3×/wk for 16 wk IG2: Yoga and flexibility 2×/wk for 16 wk	Strength: NE Aerobic capacity: PE IG1 Body composition: PE IG1 Neuromuscular control: NE		Emotional disability: PE (depression decreased among men in IG1; trend for decreased anxiety among women in IG1)
Bravo and colleagues (35)	RCT (n = 142) Community-dwelling osteopenic women Age range: 50–70 y Mean age: 60 y	IG: Weight-bearing, aerobic, and flexibility exercises 3×/wk for 12 mo IG and CG invited to attend bimonthly educational sessions	Range of motion/ flexibility: PE Neuromuscular control: NE	Walking: PE Sit/stand: PE Weighted lift task: PE	
Buchner and colleagues (59)	RCT (n = 105) HMO enrollees with impaired balance and strength Age range: 68–85 y Mean age: 75 y	IG1: Strength training IG2: Endurance training IG3: Strength and Endurance training IGs: 3×/wk for 6 mo	Strength: PE IG1 and IG3 Aerobic capacity: PE IG2 and IG3	Walking: NE Stair climbing: NE Balance: NE	Physical disability: NE
Chandler and colleagues (42)	RCT (n = 100) Community-dwelling adults who are functionally impaired Age range: 66–97 y Mean age: 78 y	IG: In-home strength training 3×/ wk for 10wk	Strength: PE	Walking: PE Chair rise: PE among more impaired participants Mobility skills: PE Balance: NE	Physical disability: NE
Cress and colleagues (50)	RCT (n = 49) Adults living independently in a retirement community or apartment Age: 70+ y Mean age: 76 y	IG: Aerobic and strength training 3×/wk for 6 mo	Strength: PE Range of motion/ flexibility: PE Aerobic capacity: PE Neuromuscular control: NE	Walking: NE Mobility: PE (Continuous Scale—Physical Functional Performance) Balance: PE	Physical disability: NE Emotional disability: NE Social disability: NE Overall disability: NE
Damush and colleagues (36)	RCT (n = 71) Women living in retirement residential communities Age: 55+ y Mean age: 68 y	IG: Strength training 2×/wk for 8 wk CG: Participants attended the exercise sessions but did not participate in exercise	Strength: PE		Physical disability: NE Emotional disability: NE
Emery and Gatz (48)	RCT (n = 48) Community-dwelling adults Age range: 61–86 y Mean age: 72 y	IG: Flexibility, aerobic activity, and strengthening 3×/wk for 12 wk CGs: Social activity group 3×/wk for 12 wk and a wait-list group	Range of motion/ flexibility: NE (trend) Aerobic capacity: NE		Emotional disability: NE
Ettinger and colleagues (39)	RCT (n = 439) Community-dwelling adults radiographic knee osteoarthritis, pain, and self-reported disability Age: 60+ y Mean age: 69 y	IG1: Walking program IG2: Strengthening program Both IGs: 3-mo facility-based program followed by a 15-mo home-based program CG: Health education program	Strength: PE both IGs Aerobic capacity: PE in IG1 Symptoms: pain decreased IG1 and IG2	Walking: PE IG1 and IG2 Sit/stand: PE IG1 and IG2 Stair ascent and descent: PE IG1 Weighted lift task: PE both IG1 and IG2	Physical disability: PE IG1

Continued on next page

Description and Outcome Summary of Late-Life Exercise Studies (*Continued*)

Study	Study Design	Exercise Program	Impairment	Function	Disability
Fiatarone and colleagues (60)	RCT (n = 100) Frail nursing-home residents Age range: 72–98 y Mean age: 87 y	IG: Resistance training 3×/wk for 10 wk CG: Social activity 3×/wk for 10 wk	Strength: PE Body composition: PE (muscle mass)	Walking: PE Stair climb: PE	
Jette and colleagues (61)	RCT (n = 102) Community-dwelling nondisabled adults Age range: 66–87 y Mean age: 72 y	IG: In-home strengthening program; one visit by a health professional to establish the program, followed by a phone call on the next day and then follow-up phone calls periodically over 11 wk; adherence goal for participants was 3×/wk for 12–15 wk	Strength: PE among younger participants		Physical disability: NE Social disability: PE among older participants Emotional disability: PE: "vigor" improved in IG among men; PE anger (older men in GC increased anger relative to older men in IG)
Jette and colleagues (38)	RCT (n = 215) Community-dwelling adults functionally impaired Age: 60+ y Mean age: 75 y	IG: Theoretically driven cognitive/behavioral resistance training program; two visits by a health professional to establish exercise and behavior change program; telephone follow-up for support and to monitor progress; incentives sent when participants adhered to intervention program for 6 mo	Strength: PE	Sit/stand with walk: PE Balance: PE	Physical disability: PE Emotional disability: NE Overall disability: PE
Judge and colleagues (62)	RCT (n = 34) Residents of two life-care communities Age range: 71–97 y Mean age: 82 y	IG: Flexibility, resistance, and balance training 3×/wk for 12 wk CG: Sitting range of motion exercise 1×/wk for 12 wk	Strength: PE	Walking: PE	
Judge and colleagues (63)	RCT (n = 110) Community-dwelling adults of a voter registration list who were able to walk 8 m without an assistive device and who had a Folstein Mini-Mental Status score >24 Age: 75+ y Mean age: 80 y	IG1: Floor and computer balance training IG2: Strength training IG3: Balance and resistance IG All IGs participated in the intervention program 3×/wk for 3 mo IGs and CG participated in five educational sessions	Strength: PE in resistance training group	Walking: NE Chair rise: NE	
King and colleagues (46)	RCT (n = 103) Inactive community-dwelling adults Age: 65+ y Mean age: 70 y	IG: Theoretically driven aerobic and strengthening program to enhance behavior change; class sessions 2×/wk, home exercise encouraged 2×/wk for 12 mo CG: Stretch and relaxation program with similar group and home program	Flexibility/range of motion: PE Aerobic capacity: PE IG Symptoms: NE	Walking: NE Sit/stand: NE Weight lift: PE	Physical disability: NE Emotional disability: NE
Kovar and colleagues (34)	RCT (n = 102) Patients with knee osteoarthritis Age range: 40–89 y Mean age: 69 y	IG: Theoretically driven supervised walking and education program to enhance behavior change 3×/wk for 8 wk	Symptoms: PE (pain decreased)	Walking: PE	Physical disability: PE
Krebs and colleagues (64)	RCT (n = 132) Community-dwelling adults with physical functioning limitations Age: 60+ y Mean age: 75 y	IG: Same as Jette and colleagues 1999 (38)	Strength: PE	Walking: PE	
Lazowski and colleagues (65)	RCT (n = 96) Long-term care residents Mean age: 80 y	IG: Strength training, balance, flexibility, and walking program 3×/wk for 16 wk CG: Range-of-motion exercise program	Strength: PE Range of motion/flexibility: PE	Walking: NE Sit/stand with walk: PE Stair climbing: NE Balance: PE	

Continued on next page

Description and Outcome Summary of Late-Life Exercise Studies (*Continued*)

Study	Study Design	Exercise Program	Impairment	Function	Disability
Lord and colleagues (66)	RCT (n = 197) Community-dwelling women Age: 60+ y Mean age: 72 y	IG: Aerobic, flexibility, and strengthening program 2×/wk for 12 mo	Strength: PE Reaction time: PE Neuromuscular control: PE	Balance: PE	
Lord and colleagues (67)	RCT (n = 160) Community-dwelling women Age range: 60–83 y Mean age: 71 y	IG: Aerobic, flexibility, and strengthening program 2×/wk for 22 wk	Strength: PE	Walking: PE Balance: PE	
McMurdo and Burnett (49)	RCT (n = 87) Community-dwelling adults in good health Age range: 60–81 y Mean age: 65 y	IG: Aerobic, strengthening, and flexibility 3×/wk for 8 mo CG: Health education (aging, exercise, nutrition, smoking, osteoporosis, and stress), six sessions over 8 mo	Strength: NE Flexibility: PE Aerobic capacity: NE Body composition: NE		Emotional disability: NE
McMurdo and Johnstone (43)	RCT (n = 86) Adults with physical disability who lived in local authority and private sheltered housing Age: 75+ y Mean age: 82 y	IG1: In-home flexibility and strengthening exercises; exercise program established by a health professional with monthly follow-up visits for 6 mo IG2: Flexibility exercise program same as IG1 CG: Monthly health education sessions delivered in the home	Strength: NE Range of motion/ flexibility: NE	Sit/stand with and without walk: NE (trend)	Physical disability: NE Emotional disability: NE
Meuleman and colleagues (37)	RCT (n = 78) Veterans Affairs nursing home and rehabilitation and community nursing home residents with disability Age range: 60–97 y Mean age: 76 y	IG: Strengthening (3×/wk) and endurance exercise (2×/wk) for 4–8 wk CG: Usual care	Strength: PE Aerobic capacity: PE	Walking: NE	Physical disability: PE among people with greater disability
Minor and colleagues (33)	RCT (n = 120) Adults with osteoarthritis or rheumatoid arthritis Age range: 21–83 y Mean age: 61 y Outcomes assessed at 3 and 12 mo (reported outcomes are 12 mo)	IG1: Walking, flexibility, and strengthening 3×/wk for 12 wk IG2: Water aerobics, flexibility, and strengthening 3×/wk for 12 wk CG: Range-of-motion exercises	Strength: PE IGs Range of motion/ flexibility: NE Aerobic capacity: PE IGs Joint count: NE Morning stiffness: PE Pain: NE	Walking: PE	Physical disability: PE Social disability: NE Emotional disability: PE
Rooks and colleagues (68)	RCT (n = 131) Community-dwelling adults, independent Age range: 65–95 y Mean age: 74 y	IG1: Strength training 3×/wk for 10 mo IG2: Walking group 3×/wk for 10 mo	Strength: PE in IC1 Reaction time (foot): PE IG1	Mobility: PE IG1 (pen pick-up from floor) Stairs: PE both IGs Balance: PE both IGs	
Rubenstein and colleagues (45)	RCT (n = 59) Community-dwelling men at risk of falling Age: 70+ y Mean age: 75 y	IG: Strength, endurance, and balance training 3×/wk for 12 wk	Strength: PE	Walking: PE Sit/stand: NE (trend) Mobility: NE (indoor obstacle course) Balance: NE	Physical disability: NE (trend)
Sharpe and colleagues (69)	Quasi-experimental (n = 139) Adults from congregate meal centers Age range: 60–91 y Mean age: 76 y	IG: Theoretically driven low-intensity exercise program to enhance behavior change for chronically impaired adults, 2×/wk for 12 mo	Strength: PE Coordination: NE	Walking: PE Balance: PE	

Continued on next page

Description and Outcome Summary of Late-Life Exercise Studies (*Continued*)

Study	Study Design	Exercise Program	Impairment	Function	Disability
Sherrington and Lord (70)	RCT (n = 42) Adults 7 mo post-fall-related hip fracture Age range: 64–91 y Mean age: 80 y	IG: Home-based, weight-bearing exercise daily for 1 mo (one visit by a health professional to establish program and one follow-up visit during intervention)	Strength: PE	Walking: PE Weight-bearing step tests: PE Balance: NE	
Skelton and colleagues (71)	RCT (n = 52) Community-dwelling women Age range: 75–93 y Mean age: 79.5 y	IG: Strengthening program, 12 wk	Strength: PE Body composition: NE	Walking: NE Sit/stand: NE Floor/stand: NE Stair climbing: NE Kneel rise time: PE Weighted lift task: NE Balance: NE	
Stewart and colleagues (44)	Quasi-experimental (n = 89) Adults living in low-income congregate housing facilities Age range: 62–91 y Mean age: 76 y	Theoretically driven intervention (CHAMPS) designed to increase physical activity in existing community programs. Length of follow-up: 6 mo			Physical disability: NE Social disability: NE Emotional disability: PE among participants who adopted and maintained new activity
Wolfson and colleagues (72)	RCT (n = 110) Community-dwelling adults who were registered to vote Age: 75+ y Mean age: 80 y	Same intervention as Judge and colleagues 1994 Intervention duration for all IGs: 3 mo; all subjects then received 6-mo weekly Tai Chi (results reported here are at 3-mo follow-up)	Strength: PE IG2 and IG3	Gait: NE Balance: PE IG1 and IG3	

Note: RCI = randomized control trial; IG = intervention group; PE = positive effect; NE = negative effect or control group improved; CG = control group; CHAMPS = Community Healthy Activities Model Program for Seniors.

†Intervention groups engaged in at least 45 min of exercise unless otherwise indicated. Control groups engaged in usual activity, were waitlisted, or given no information unless otherwise indicated.

‡Positive effect (intervention group improved compared with control group or intervention group maintained and control group declined).