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Part G. Section 6: Functional Health

Introduction

This chapter reviews evidence related to the effects of physical activity on improving functional health and/or preventing disability in middle-aged and older adults. Background information is provided, followed by an assessment of the evidence related to 3 questions about possible health benefits of physical activity.

Conceptual Model and Terminology

The term "disability" has been defined in several different ways in scientific models of disability (1;2). In this chapter, "disability" is used as an umbrella term to refer to deficits in overall health that affects a person's ability to do tasks of everyday life. That is, disability is the other side of the coin of health — a reasonably (though not perfectly) healthy person has a lot of health, but also a little disability. Measures of physiologic impairment, functional limitations, and role limitations assess the status of basic aspects of the disablement process.

A thorough discussion of the existing conceptual frameworks used to model and describe the disablement process is beyond the scope of this discussion. However, 3 basic concepts, which are included in several models of disability, are often used when discussing this process, and they provided a conceptual foundation for the Functional Health subcommittee's evidence review and deliberations (1;2).

- *The capacity of the physiologic systems of the body* (which depends upon the status of physiological functions and anatomical structures). We refer to this concept as "physiologic capacity," and loss of physiologic capacity is referred to as "physiologic limitation." Examples of physiologic capacity relevant to this section include measures of physical fitness such as aerobic power (VO_{2max}) and muscle strength. A recent review by Paterson and colleagues provides evidence that physical activity programs improve physiologic capacity in older adults (3).

- *The capacity of a person to perform a task, activity, or behavior in a controlled environment that neither enhances nor impairs behavioral abilities.* We refer to this concept as "functional ability," and loss of functional ability is referred to as "functional limitations." Examples of functional abilities include ability to walk at a normal speed on a flat surface, and ability to climb a typical flight of stairs.

- *The capacity of a person to perform a task, activity, or behavior in his or her actual environment, so as to fulfill the roles a person assumes in life.* We refer to this concept as “role ability,” and loss of role ability is referred to as “role limitations.” We live in environments that contain physical and social factors that facilitate or impair ability to perform roles. A person who cannot walk several hundred meters cannot perform the task of grocery shopping in a large grocery store and fulfill the role of family food shopper. But he or she can perform the task in a small store or in a store with motorized carts. Measures of role performance include activities of daily living (ADL) and instrumental activities of daily living (IADL) scales.

Another term that is key to this chapter and to the health of older adults is “fall.” A fall is defined as unintentionally coming to rest on the ground, floor, or other level lower than one’s starting point (4). Falls in older adults can be classified into 3 main groups. About 20% of falls result from an external precipitant, such as being tripped up by a large, rambunctious dog while out for a walk. This type of fall is simply the consequence of an active lifestyle, and not the result of a disablement process. Another 20% of falls are due to a single identifiable cause, such as a drug-related syncope, stroke, or Parkinson’s disease. Adults with such falls require diagnosis and specific therapy directed at the single major cause. The majority of falls, though, result from multiple etiological or causative factors interacting that put older adults at risk of falling. This chapter is concerned with the prevention of this type of fall. Characteristically, falls of this type have only minor provocation, such as tripping on a step or loose rug. Epidemiologic studies suggest that decline in muscular strength, speed of reaction, and balance are key factors in fall risk (4;5). It is well documented that older adults with functional limitations are at increased risk for falls and their sequelae, such as fractures of the wrist and hip. Hence, these falls are regarded as a result of the disablement process in older adults.

Functional Health in Middle-Aged and Older Adults

The etiology of disability differs strongly by age. Disease-related disability affecting middle-aged and older adults accompanies well-known, common diseases, such as cardiovascular disease, depression, diabetes, stroke, arthritis, and dementia (6;7). The effects of such diseases on disability are compounded by loss of physiologic capacity due to biologic aging, such as decline in aerobic capacity, muscle strength, and balance (8;9). The models of disability in older adults involve concepts like frailty, where the capacities of multiple physiologic systems are markedly reduced.

In contrast, disability in younger age groups is much less prevalent, is much less likely to be due to such chronic diseases, and is not compounded by declines associated with aging. It involves, for example, developmental disabilities, genetic syndromes, and traumatic injuries. Because of the difference in pathogenesis by age, it is appropriate to separate the evidence review of disability in children and young adults from the evidence review in older adults. This chapter reviews the evidence for older adults.

The Importance of Reducing Disability and Falls in Older Adults

Older adults have the highest prevalence of disability (10) and falls (4) of any age group in the population. Studies consistently show that the prevalence of both major disability and falls increases with age, and is higher in women than men. As the life expectancy of older Americans continues to increase, the burden of disability in older populations is also expected to increase. The Medicare Current Beneficiary Survey (MCBS) is particularly useful for characterizing disability in older adults, as it includes persons living in the community and persons living in long-term care facilities (11). In 2003, the MCBS characterized mobility limitation as difficulty walking a quarter of a mile. In men, the prevalence of mobility disability was 31% for those aged 65 to 74 years, 46% for those aged 75 to 84 years, and 69% for those aged 85 years and older. Corresponding percentages in women were 42%, 57%, and 81% (11). In a community population aged 70 years and older, around one third of people will fall in any 1 year (4). In a recent US survey, approximately 5.8 million persons aged 65 or older fell in the preceding 3-month period (12). Fall rates increase with age and are higher in women than men. Fall-related injuries can have a large adverse effect on functional ability in older adults and can sometimes directly result in death (5;13-15).

Disabilities and falls have a significant impact on the ability of older adults to live independently, and the treatment and management of disability and falls in older adults consume enormous resources involving both medical care and long-term care (16-18). One can hardly overestimate the importance of independent living to quality of life in older adults.

National surveys consistently show that older adults are the least active age group of Americans. For example, national survey data from 2005 show that an average of only 21% of people aged 65 years and older report meeting recommended levels of physical activity, with women reporting slightly less physical activity participation rates than men (19). A recent national survey using an objective measure of physical activity (accelerometers) suggests older adults may be substantially less active than they report on questionnaires (20). If physical activity prevents or delays disability, the majority of older Americans stand to benefit.

Review of the Science

Overview of Questions Addressed

This chapter addresses 3 major questions:

1. In middle-aged and older adults who do not have severe functional or role limitations, does regular physical activity prevent or delay the onset of substantial functional limitations and/or role limitations?

2. In older adults, who have mild, moderate, or severe functional or role limitations, does regular physical activity improve or maintain functional ability and role ability with aging?

3. In older adults who are at increased risk, does regular physical activity reduce rates of falls and fall-related injuries?

Data Sources and Process Used To Answer Questions

The Functional Health subcommittee used the *Physical Activity Guidelines for Americans* Scientific Database as its primary source of literature since 1995 to review all 3 questions (see ***Part F: Scientific Literature Search Methodology,*** for a full description of the Database). The subcommittee then used the reference lists from those papers as well as the collective expertise of its members and consultants to identify additional relevant publications, meta-analyses, and systematic reviews.

Question 1: In Middle-Aged and Older Adults Who Do Not Have Severe Functional or Role Limitations, Does Regular Physical Activity Prevent or Delay the Onset of Substantial Functional Limitations and/or Role Limitations?

Conclusions

Strong, consistent observational evidence indicates that mid-life and older adults who participate in regular physical activity have reduced risk of moderate or severe functional limitations and role limitations. Active mid-life and older individuals — both men and women — have approximately a 30% lower risk of developing moderate or severe functional limitations or role limitations compared with inactive individuals. The observational evidence of benefit is strong for aerobic activity, but limited for other types of activity (muscle-strengthening, balance, and flexibility activities). It should be noted that no randomized controlled trials (RCTs) were available to answer Question 1.

Several important findings from the literature review support this conclusion:

- The results were strongly consistent across studies;

- In studies with repeated measures of physical activity during follow-up, adults who reported regular physical activity at all measurement occasions were at lowest risk of functional limitations; and

- Studies that assessed change in physical activity over time reported that change from lower levels of activity to higher levels of activity over time was associated with reduced risk of limitations.

Introduction

The aging of the American population has led to large numbers of older persons (aged 65 years and older), with a rapidly expanding proportion reaching advanced old age (85 years and older), a category termed the oldest old (21). This population includes large numbers of older adults who have no difficulty or only mild difficulty living independently in the community (11;22). That is, such older adults have no or mild functional limitations and role limitations. Across the population, older adults strongly wish to avoid major functional limitations and major role limitations that would lead to dependent living. Hence, Question 1 asks a primary prevention question: Does physical activity prevent or delay onset of moderate or severe functional limitations and/or role limitations in middle-aged and older adults?

It is theoretically possible to answer this question using a large RCT. The problem is that such trials are extremely difficult and expensive, and to our knowledge such a study has never been done. Analogous to other primary prevention studies regarding lifestyle, such as tobacco or nutrition, information about prevention comes from observational studies, including both prospective and retrospective cohort studies. Cohort studies of physical activity and disability generally use one of 2 approaches. Some studies use a dichotomous measure of disability (e.g., presence or absence of inability to walk 400 meters) as an outcome, and compare rates of incident disability in people with different levels of physical activity. Other studies use a continuous measure of disability (e.g., the Health Assessment Questionnaire-Disability Index) and compare the rate of decline in people with different levels of physical activity (23).

Conceptually, the cohort studies can also be divided into 2 types based upon the population they recruit. A “pure” primary prevention study would include adults and older adults with either no limitations or mild limitations at baseline, and assess whether physical activity prevents or delays onset of moderate or severe limitations. The other approach is to assess whether physical activity prevents severe limitations in a population that includes adults with no, mild, or moderate limitations. Both types of studies exist and were used to address the question.

Given decades of research showing that physical activity in healthy adults (including healthy older adults) improves physiologic capacity and hence functional ability (e.g., ability to walk a mile), one might ask, “Doesn’t this mean physical activity prevents disability?” A response to this question is that the pathogenesis of decline in older adults is complex, with many causal factors and etiologic pathways involving a large number of diseases. The improvement in physical fitness and physical performance is one mechanism by which physical activity can prevent decline. The reduction in the incidence of chronic diseases (e.g., ischemic heart disease, depression, type 2 diabetes) is another mechanism by which physical activity can prevent decline. However, a more meaningful question is whether the net effect of physical activity across all etiologic pathways (only some of which are influenced by physical activity) is sufficient to have a meaningful effect size on the incidence (or rate) of moderate or severe limitations in older adults.

Rationale

The Scientific Database was the primary source of studies for review to answer Question 1. Additional research studies (not in the Database) were identified by review of reference lists of published studies. The subcommittee members and consultants also identified papers for consideration based upon their expertise and knowledge of the field. Information from the articles was systematically abstracted and summarized in the tables and figures accompanying the chapter. The search of studies was limited to studies published between 1995 and 2007. In addition, a supplemental PubMed search was performed to find reviews of the literature between 1990 and 2007.

Specifically, we sought only cohort studies (including both prospective and retrospective studies) that measured the physical activity level of participants at baseline as the exposure variable, and assessed either functional limitations or role limitations during follow-up as an outcome variable. As indicated above, these studies were of 2 types: (1) the study sample at baseline included adults with only no or mild functional limitations or role limitations; and (2) the study sample at baseline included adults with none, mild, or moderate functional limitations or role limitations. We regarded ADL limitation as an indicator of severe role limitations. Studies that examined only the relation between physical fitness and risk of functional/role limitations were not included in the review.

Twenty-eight prospective cohort studies addressed the relation between physical activity and risk of functional limitations and role limitations (23-50). Table G6.A1 provides a summary of the studies. (Table G6.A1, which summarizes these studies, can be accessed at http://www.health.gov/paguidelines/report/.) Almost all these prospective cohort studies reported that active adults had a lower incidence of functional and role limitations. Only 4 studies did not find a significant relation between physical activity and risk of functional or role limitations (26;31;43;48). However, statistical power was limited in some of these negative studies, as illustrated by a study where the confidence interval (CI) on one adjusted odds ratio of .91 ranged from .22 to 3.70 (31) and a study where a 23% reduction in risk was not statistically significant (48). Both of the other two studies were not significant at the 0.05 level, but were very close (26;43).

The findings were consistent across different types of outcome measures that included measures of functional limitations as well as role limitations, including measures of mobility, ADL, IADL, measures of overall ("global") functional and role limitations, and occupational status. In studies that used an odds ratio or hazard ratio to quantify the risk reduction, 19 studies reported at least a 30% lower risk (a ratio or 0.70 or less) when comparing the most active to the least active subgroups of adults. Studies with repeated assessments of physical activity consistently reported that adults who were regularly active during follow-up had the lowest risk of disability (30;32;34;36). The 2 studies that assessed change in physical activity level during follow-up consistently reported that adults who switched from inactive to active during follow-up had a lower risk of limitations than adults who remained inactive (23;48). One study also measured aerobic fitness (using a treadmill test) (32). Although both physical activity and aerobic fitness were each associated with significantly reduced risk of functional limitations over time for both men and women, the aerobic fitness provided even greater risk reduction (OR 0.30) (32).

Dose-Response Pattern

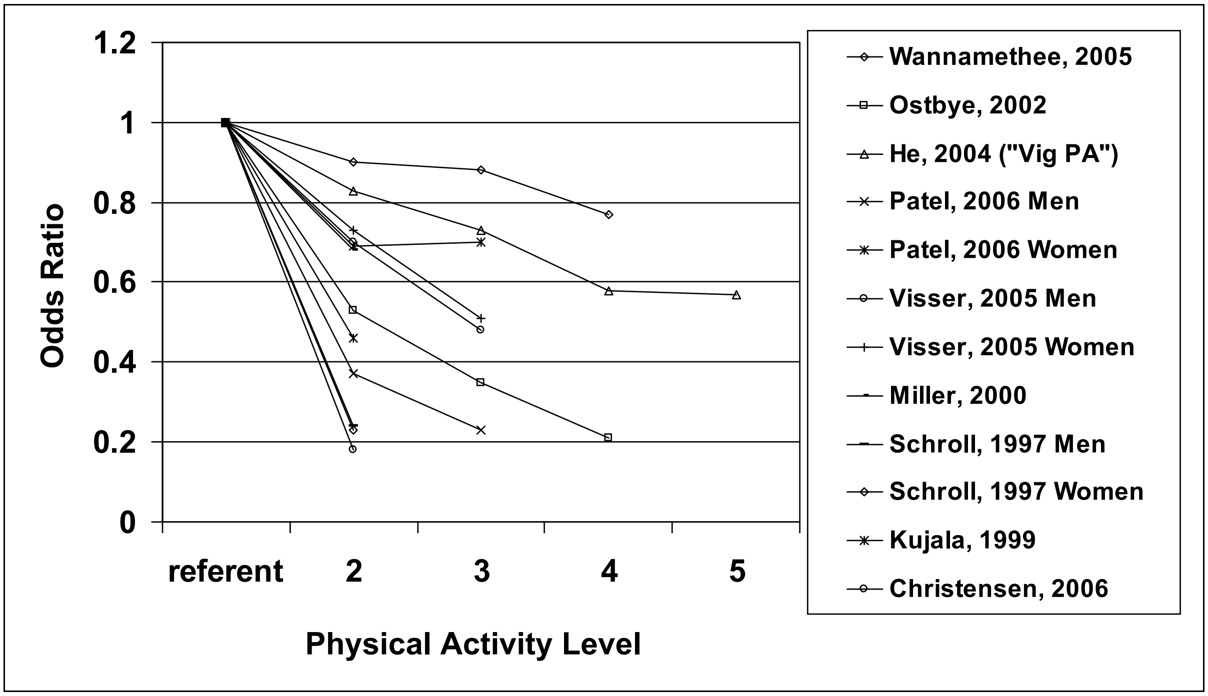
The findings from the prospective cohort studies support a dose-response effect, where greater amounts of physical activity were associated with lower risk of limitations. Figure G6.1 shows data from prospective cohort studies with measures of mobility limitations. Figure G6.2 shows data from studies with ADL, IADL, and/or global measures. When studies reported a statistical test of trend across categories of physical activity, the trend was statistically significant (29;30;32;34;36;37) with one exception where P=0.08 (48).

Because of the diversity in methods used to assess physical activity, it was not possible to reach a conclusion about the amount of risk reduction that occurs from a specific amount of physical activity. However, a reasonable conclusion is that adults who do moderate amounts of activity for the purposes of reducing risk of common chronic diseases also would reduce risk of functional and role limitations.

Generalizability of Findings

The research supports the conclusion that the findings are widely applicable to older adults. Some studies, such as the Longitudinal Study of Aging and the Health and Retirement Study, enrolled nationally representative samples (29;35;36). Many others involved a systematic sample of a specific geographic area within a country, such as a city. About half the prospective cohort studies enrolled samples that included adults aged 85 years and older, thereby providing evidence that the oldest old benefit from physical activity (although most did not analyze data separately for that age group). Most studies enrolled both men and women. Studies that did separate analyses for men and women commonly reported significant benefits for both (28;32;37;40;46). Almost all studies were done in the United States or Europe, though one study (50) was from Taiwan and one study (42) was from Israel. Although the studies did not directly compare the effect of physical activity among different race/ethnic groups, no evidence suggested that effects of physical activity would not occur in all race/ethnic groups. It could not always be ascertained with certainty, but it appeared about half the studies enrolled adults with no or mild limitations, and about half the studies enrolled adults with no, mild, or moderate limitations. We located only one study that included objective measures of both physical activity and of functional limitations (25). Four studies measured some outcome related to physical fitness or functional ability in addition to physical activity and functional limitations (25;32;38;40).

Figure G6.1. Prospective Cohort Studies With Measurement of Mobility Limitations

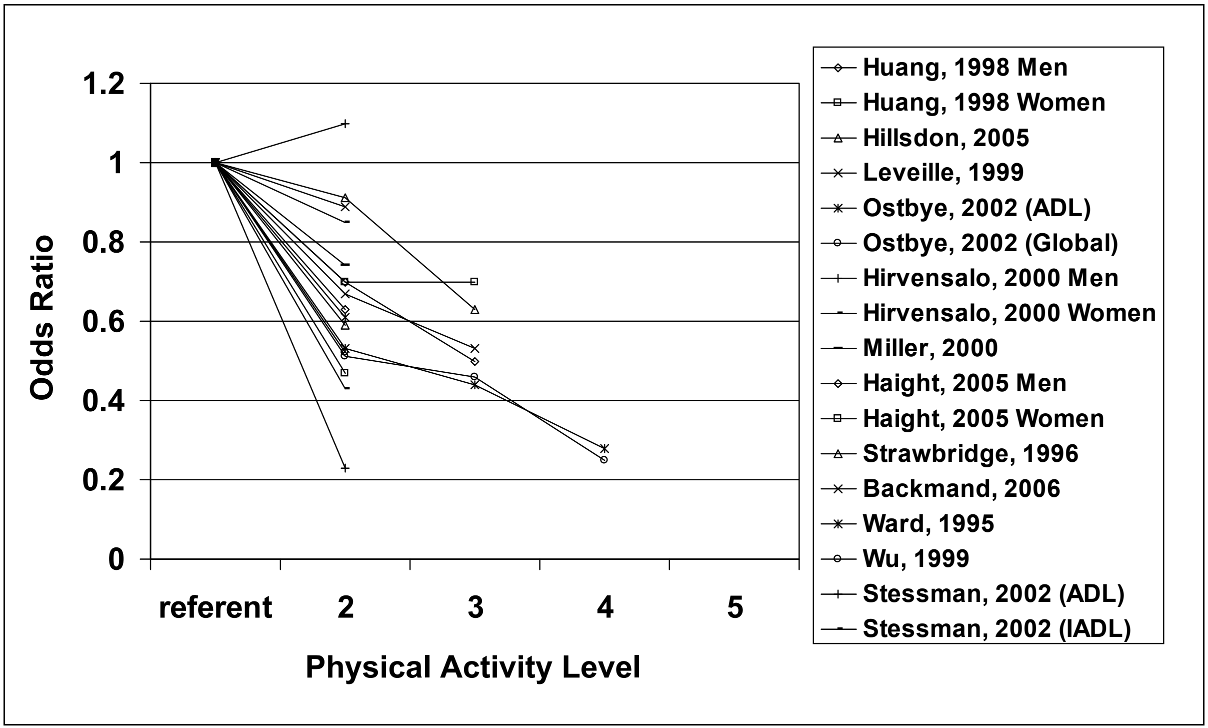


Legend: The figure shows the reported odds ratio for each category of physical activity (PA), with the lowest category of PA assigned as the referent category. For example, the Wannamethee study had four categories of PA, with category 1 (the referent) assigned to those with the lowest level of PA, category 4 assigned to those with the highest activity level, with all categories forming an ordinal scale.

Figure G6.1. Data Points

	Referent	2	3	4	5
Wannamethee et al., 2005 (48)	1	0.9	0.88	0.77	
Ostbye et al., 2002 (36)	1	0.53	0.35	0.21	
He et al., 2004 ("Vigorous PA") (29)	1	0.83	0.73	0.58	0.57
Patel et al., 2006 Men (37)	1	0.37	0.23		
Patel et al., 2006 Women (37)	1	0.69	0.7		
Visser et al., 2005 Men (46)	1	0.7	0.48		
Visser et al., 2005 Women (46)	1	0.73	0.51		
Miller et al., 2000 (35)	1	0.68			
Schroll et al., 1997 Men (40)	1	0.24			
Schroll et al., 1997 Women (40)	1	0.23			
Kujala et al., 1999 (33)	1	0.46			
Christensen et al., 2006 (26)	1	0.18			

Figure G6.2. Prospective Cohort Studies With Measures of ADL, IADL, and Global Outcomes



Legend: ADL, activities of daily living; IADL, instrumental activities of daily living. The figure shows the reported odds ratio for each category of physical activity, with the lowest category of physical activity assigned as the referent category. For example, the Huang study had three categories of physical activity, with category 1 (the referent) assigned to those with the lowest level of physical activity, category 3 assigned to those with the highest activity level, with all categories forming an ordinal scale.

Figure G6.2. Data Points

	Referent	2	3	4	5
Huang et al., 1998 Men (32)	1	0.7	0.5		
Huang et al., 1998 Women (32)	1	0.7	0.7		
Hillsdon et al., 2005 (30)	1	0.91	0.63		
Leveille et al., 1999 (34)	1	0.67	0.53		
Ostbye et al., 2002 (ADL) (36)	1	0.53	0.44	0.28	
Ostbye et al., 2002 (Global) (36)	1	0.51	0.46	0.25	
Hirvensalo et al., 2000 Men (31)	1	1.1			
Hirvensalo et al., 2000 Women (31)	1	0.85			
Miller et al., 2000 (35)	1	0.74			
Haight et al., 2005 Men (28)	1	0.63			
Haight et al., 2005 Women (28)	1	0.47			
Strawbridge et al., 1996 (43)	1	0.59			
Backmand et al., 2006 (24)	1	0.89			
Ward et al., 1995 (49)	1	0.61			
Wu et al., 1999 (50)	1	0.52			
Stessman et al., 2002 (ADL) (42)	1	0.23			
Stessman et al., 2002 (IADL) (42)	1	0.43			

Limitations

The conclusions for Question 1 have several caveats. First, because all of the studies in the evidence base were observational epidemiologic studies with no RCTs, the data cannot prove causality of effect. Some concern exists that the prospective cohort studies could not adequately adjust for confounders and may have overestimated the effect. Healthy people are more physically active than are people with health conditions, and adjusting for all health status differences between physically active and sedentary persons is not possible in these studies. However, the consistency of evidence does support a cause-and-effect relation between physical activity and lower risk of functional and role limitations. In addition, plausible biological mechanisms — demonstrated in RCTs — exist for physical activity to improve physiologic capacity (e.g., aerobic power, strength, balance) and functional ability in older adults (see Question 2). These are all important factors in the causal pathway toward disability.

Second, although evidence indicates that regular aerobic activity prevents functional and role limitations, evidence of a beneficial effect of muscle strengthening activities, balance activities, and flexibility activities is insufficient. Two additionally reviewed studies analyzed measures of leg strength, with one reporting that higher leg strength reduced risk of limitations (51) and another essentially reporting no association (40).

Third, although the literature provides sufficient evidence of a dose-response effect (i.e., the more physical activity, the greater the preventive effect), it is difficult to make statements about the amount of physical activity required for substantial preventive effect. It was common for studies to use simple measures of self-reported physical activity (e.g., frequency and duration of walking activities), but not to provide information of the validity of the measurement method. All the studies but one (25) relied upon self-report measures of physical activity and most used self-report measures of functional and role limitations. Additional studies that use objective measures of physical activity and objective measures of functional ability are needed.

Finally, data are insufficient to determine whether the preventive benefits of physical activity differ by race or ethnic group. Some studies enrolled representative samples of the US older adult population, but few studies directly compare the effects of physical activity across race or ethnic groups.

Question 2: In Older Adults Who Have Mild, Moderate, or Severe Functional or Role Limitations, Does Regular Physical Activity Improve or Maintain Functional Ability and Role Ability With Aging?

Conclusions

Modest evidence indicates that regular physical activity in older adults with existing functional limitations improves functional ability. Due to the lack of well-designed intervention trials, only limited evidence is available to conclude that physical activity in older adults with existing functional limitations improves or maintains role ability with aging.

Most of the physical activity interventions included both aerobic (especially walking) and muscle strengthening activities, with fewer interventions using only a single type of activity. For this reason, most evidence reflects a pattern of physical activity that involves periods of 30 to 90 minutes of moderate to vigorous physical activity, on 3 to 5 days per week, in which most of this time is devoted to aerobic activity and muscle strengthening activity and with a shorter amount of time spent on other forms of activity, such as flexibility. When it was possible to determine the amount of time spent just on aerobic activity (mostly walking), it usually varied from 60 minutes per week to 150 minutes per week. Because of low baseline fitness levels in older adults, "relative intensity" should be used for determining exercise intensity instead of absolute intensity. Evidence is limited that physical activity levels less then described above provide some benefit.

Introduction

Some older adults already have functional limitations and role limitations. However, prevention of further decline is still relevant for these older adults and this is the focus of Question 2. In people with existing diseases or limitations, concern always exists that the disease processes are so advanced that they are difficult to influence. Question 2 can be thought of as asking whether it is "too late" for people with existing limitations to benefit from physical activity.

Both RCTs and observational studies have been conducted to address Question 2. The RCTs address whether the rate of change ("decline") in functional or role limitations differs between a control group and a physical activity group. The observational studies and RCTs provide complementary information, in that observational studies can address the effects of years of regular physical activity (though residual confounding, resulting from differences between people who choose to exercise versus those who do not that cannot be fully adjusted for, is a threat to their validity), while few existing randomized trials have studied more than 12 months of regular physical activity (but randomization greatly reduces the risk of confounding).

Rationale

The sources of research studies was the same as for Question 1 – studies published between 1995 and 2007, relying mainly on the Scientific Database for locating the studies. The Functional Health subcommittee included only RCTs and prospective cohort trails that included adults aged 60 years or older with functional limitations and role limitations and recruitment of 25 subjects or more. We excluded papers if they focused on a specific disease (e.g., dementia) or subjects who were hospitalized at the start of the trial. We excluded studies in healthy adults with no limitations. We included only studies whose primary purpose was to determine whether physical activity affected functional health. Some of these studies recruited only participants with mild to moderate functional limitations, and some recruited a mix of participants with no, mild, or moderate limitations. Because of incomplete information on functional ability in participants in many studies, we could not always ascertain the range of functional ability of the study sample. It should be noted that the subcommittee did not review studies focusing on arthritis and functional health, as this topic is covered in ***Part G. Section 5: Musculoskeletal Health.***

Fourteen trials were reviewed to answer this question: 12 RCTs (52-63) (Table G6.A2) (Table G6.A2, which summarizes these studies, can be accessed at http://www.health.gov/paguidelines/report/.) and 2 prospective cohort studies (31;41) In addition, 4 review papers considered this issue (64-67). The sample size in the RCTs ranged from 39 to 486 subjects. The prospective cohort studies had samples of slightly more than 1,000 subjects (31;41). All of the subjects in these studies were older adults aged 65 years or older. All of the RCTs recruited subjects who were sedentary. The baseline health status of the subjects varied. Eight of the RCTs recruited people with functional limitations (52;55;57;58;60-63); 4 of the trials recruited subjects both with and without functional limitations (53;54;56;59). In most of the studies, the subjects were older adults who lived in the community. Only one study enrolled adults living in a residential-care facility (55).

All but one of the randomized trials used multimodal interventions that included a mixture of aerobic activity, balance training, strength training, and/or physical therapy guided functional training. One study used a single intervention of muscle-strengthening or power activities (60). The format of the interventions varied. Some of the interventions were supervised group sessions held in community settings, some took place in the home (supervised or unsupervised), and still others were a mixture of the two. The frequency and duration of the interventions also varied, though the majority of interventions took place 3 to 5 days per week and lasted between 40 and 90 minutes. The length of the interventions ranged from 1.5 months to 18 months.

There are no universally agreed upon "functional ability" outcomes. For this reason, it was very difficult to review and compare the literature. The Subcommittee therefore deliberately decided to be liberal in selecting the criteria of outcomes related to functional ability. The outcomes reported in the reviewed trials included, among others, gait speed, timed walking tests, functional reach, and "get up and go," as well as performance on observational functional health instruments such as the Short Physical Performance Battery (SPPB), Physical Performance Test (PPT), McArthur Battery Scores, and functional obstacle course. The subcommittee also reviewed trials that recorded self-reported functional health using instruments such as the Functional Status Questionnaire and the SF-36 (the emotional health SF-36 subscale was not reviewed). ADLs and IADLs were measured using a variety of standardized questionnaires. All of the trials demonstrated an improvement in one or more functional ability outcomes. A reasonable question is whether the magnitude of change seen in these trials on functional ability can affect role limitations or ability. Most trials were underpowered to examine this question and did not measure ADLs or IADLs.

The most recent, and one of the largest trials to date to address physical activity and functional ability, is the Lifestyle Interventions and Independence for Elders Pilot (LIFE-P) trial (62). LIFE-P examined the effects of a mixed-modal physical activity intervention on functional performance. The trial included 424 men and women aged 70 to 89 years who had mild to moderate functional limitations at baseline. The participants were randomized to either a multi-modal exercise group or an attention-matched control group. The people in the exercise group participated in a combination of aerobic, strength, balance, and flexibility exercises (with primary emphasis on walking). The muscle strengthening and flexibility exercises focused on lower body extremity exercises. Subjects spent the first 8 weeks (adoption) attending 3 supervised center-based sessions per week. The sessions lasted 40 to 60 minutes each. During the next 4 months (transition), the number of center-based sessions was reduced to 2 times per week, and home-based endurance/strength/flexibility exercises were started (3 or more times per week). The subsequent maintenance phase consisted of the home-based intervention, with optional once to twice per week center-based sessions. The primary goal was to walk 150 minutes per week at a moderate intensity. The intervention also included a strong behavioral component, with the participants receiving 10 group-based behavioral counseling sessions during the first 10 weeks. The average walking time during the maintenance phase was 138 minutes per week; average frequency of moderate physical activity per week was 6.4 times per week at 6 months and 5.1 times per week at 12 months. The people in the attention-control group participated in a health education program. In this trial, adverse events were carefully monitored and each group had similar rates of non-serious and serious adverse events. The LIFE-P trial found that, compared to those in the health education program, the people who participated in the exercise intervention were able to significantly improve both their SPPB and 400-meter walking speed during the 1.2-year intervention ($P<0.001$). This pilot study also showed a trend toward a reduction in the risk of major mobility disability (i.e., inability to walk 400 meters) (hazard ratio = 0.71, CI 0.44 to 1.20) although this pilot study was not powered for this outcome. In another recent large study (n=486) in very old men and women (85 years or older) in Finland, a multi-dimensional 17-month intervention that included exercise (walking, group exercises, and/or home exercises) demonstrated no improvements in ADLs. However, mobility score and balance improved more in the intervention group than in controls (58).

The Women's Health and Aging Study (WHAS) was a longitudinal cohort study that met the criteria for inclusion in this review (41). In this study, 1,002 women aged 65 years and older who had functional limitations at baseline were recruited. Of the 800 functionally limited women who could walk unassisted at baseline and were alive and contacted 1 year later, 226 (28%) walked regularly at least 8 blocks per week. These women exhibited better health and functioning than did non-walkers. In addition, walkers were 1.8 times more likely (95% CI 1.2 to 2.7; $P=0.002$) to maintain reported walking ability and showed less decline in customary walking speed and functional performance score over the follow-up period. A Finish cohort study of 1,109 men and women (aged 65 years or older) were followed for 8 years (31). Subjects at baseline were either functionally impaired or had no functional limitations and all subjects (regardless of functional status) were categorized as being sedentary or active. Among those who were impaired at baseline, those who were active had a reduced risk of becoming dependent (role limitation) over the 8-year follow-up.

Four relevant systematic review papers focused on different aspects of functional health (64-67). The most recent review was that of Baker and colleagues (64). The authors limited their review to only randomized controlled exercise trials of at least 3 modalities of training, e.g., strength, aerobic, and balance. The 3 modes of training had to be conducted concurrently. Many interventions have focused on these 3 modes of exercise in combination because older adults who are at risk of functional limitations generally have deficits in these areas. Therefore, it makes sense to target these areas with a multi-modal exercise program. In addition, the review only considered trials with subjects aged 60 years or older. The authors systematically reviewed 15 studies totaling 2,149 subjects. A low effect size was seen for changes in dynamic strength (mean 0.41, range −0.08 to 1.67), and balance improved in only 6 of the 11 studies that included balance as an outcome (the positive effect on reducing falls is reported in Question 3). The authors concluded that the effect size for functional health changes were minimal when all studies were considered. The authors gave a number of reasons for the low effect size of these multi-modal interventions on functional health. One reason was that a ceiling effect may have prevented further improvement in some functional measures, as many of the trials reviewed included subjects with high baseline functional ability. However, the authors posited that the most likely reason for a small effect size was that the intensity and duration of any given modality was not robust enough to elicit meaningful physiologic changes that could affect functional health. The authors of the review suggest that more evidence is needed to establish whether multi-modal exercise at adequate volumes and intensity is feasible and effective in older populations and whether multi-modal interventions are in fact more effective than single mode interventions. The LIFE-P study described above and the study of Binder and colleagues (52) were exceptions to the findings in this review, as these 2 studies did show better outcomes. This is most likely due to the size of these studies, the functional limitations of the subjects at baseline, robust interventions, objectively measured primary outcomes, and the length of the trials.

Keysor and Jette reviewed 31 studies (28 RCTs and 2 quasi-experimental trials) that examined the impact of various physical activity programs on functional activities and/or disabilities among older adults (65). The mean age of subjects was older than age 60 years, although the trials had no lower age limit for inclusion. Sample sizes of the trials ranged from 24 to 439. The most consistent positive effects of exercise were observed in strength, aerobic capacity, flexibility, walking, and balance, with more than half of the trials that examined these outcomes finding positive effects. Of the studies that examined physical, social, emotional, and overall disability outcomes, most found no improvements. Only 5 of the studies in the review reported reduced physical disability. The authors of the review note that methodological issues may be one of the main limitations in the studies that have examined disability outcomes. In another critical review by Keysor in 2003, the overall conclusions were similar (67). Exercise increases muscular strength and aerobic capacity and improves functional ability. However, it is less clear whether physical activity or exercise prevents or minimizes disability.

The fourth review considered for Question 2 was that of Latham and colleagues (66). In this review, the authors focused solely on progressive resistance strength training interventions trials in older adults (aged 60 years and older). The authors identified 62 trials with a total of 3,674 subjects. The authors noted that most studies were of low quality due to poor design, small numbers, unclear randomization schemes, and other problems. Progressive resistance strength training showed a strong positive effect on strength and the training had a modest effect on some measures of functional limitations such as gait. No evidence of an effect was found for physical disabilities in the 14 studies that reported disability outcomes. It is important to note that the main objective of most of the trials in the review was not to reduce disability. (Muscle strengthening activities are addressed more fully in ***Part G. Section 5: Musculoskeletal Health.***)

Sex and Race/Ethnicity

Men and women have been represented about equally in the exercise trials that were reviewed. Although not systematically tested, no evidence appears that older men and women respond differently to exercise interventions focusing on functional health. Many of the studies demonstrated that men had higher physiologic and functional status than women at any given age. No trials reviewed for this question had adequate numbers of non-whites to do sub-analyses to determine whether responses to exercise differ among racial or ethnic groups.

Comparison to Current Guidelines

Current recommendations from the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) recommend that older adults participate in moderate to vigorous intensity aerobic activity, muscle strengthening activity, and activities to maintain or increase flexibility; balance exercises are recommended for older adults at risk of falls (68). Out of the 12 randomized trials reviewed, 8 roughly met the recommendations outlined by ACSM/AHA (52;54;56;57;59;61-63). The LIFE-P Trial and the studies by Binder and colleagues and Nelson and colleagues saw robust improvements in functional ability. The study of Binder and colleagues also saw an improvement in aerobic capacity (VO_{2max}). The effects of the interventions on functional ability were not as robust in the studies of Cress and colleagues and King and colleagues. This is most likely due to the fact that the subjects in these two trials had higher functional ability at baseline, as both studies recruited older subjects with and without functional limitations at baseline. It is important to note that muscle strength and aerobic capacity (VO_{2max}) improved in the study of Cress and colleagues demonstrating an improvement in physiologic capacity that was accompanied by modest improvements in functional ability. Also of note, the study of King and colleagues used “flexibility” exercises as their attention-control group (57). The subjects in this group had greater reductions in self-reported bodily pain. This is one of the only studies to investigate flexibility exercises.

Limited evidence suggests that functional health in older adults can be improved with less frequent physical activity than recommended by the ACSM, as the other 4 trials reviewed used interventions below this threshold and each demonstrated some improvements in function ability (53;55;58;60).

Question 3: In Older Adults Who Are at Increased Risk, Does Regular Physical Activity Reduce Rates of Falls and Fall-Related Injuries?

Conclusions

Clear evidence demonstrates that participation in physical activity programs is safe and can effectively reduce falls in older adults at elevated risk of falls. Limited evidence indicates that physical activity programs reduce injurious falls in older adults. Currently, the evidence is strongest for physical activity interventions that include muscle strengthening and balance training activities in combination with aerobic activities, especially walking. In addition, moderate, but inconsistent, evidence shows that tai chi exercise or balance-only training programs provide benefit.

Most of the interventions reviewed included a pattern of physical activity that involves 3 times per week of balance and moderate intensity muscle-strengthening at 30 minutes per session, with additional encouragement to participate in moderate-intensity walking activities 2 or more days per week for 30 minutes a session. It was difficult to ascertain an optimal dose for tai chi, as risk reduction was seen in one trial with as little as 1 hour per week, whereas other trials had greater frequency (e.g., 3 days per week). Limited evidence suggests that physical activity levels less than those described above provides some benefit.

Introduction

It is not until age-related decline in muscle strength and stability reaches a critical threshold that the risk of falls and functional decline threaten independent living. This threshold occurs when the daily activities of life are at or near the limit of a person’s physiologic capacity (e.g., muscle strength and balance). Minor perturbations may precipitate the fall, but it appears from epidemiologic studies that the underlying cause is the person’s critically compromised physical fitness — particularly strength and balance (69). Theoretically therefore, only small improvements in strength and balance may be needed to lift the person above the threshold where daily living activities are hazardous.

Numerous RCTs of interventions to prevent falls have been conducted in older adults. A multi-component approach is now recommended to address factors that increase fall risk (69), and so trials now commonly test multi-component interventions. These components include removal of environmental hazards (e.g., loose mats), medical treatment (e.g., eliminating drugs that increase fall risk), and physical activity. However, it is difficult to deduce *post-hoc* which elements of a multi-component intervention are efficacious, so the literature on multi-component interventions was not reviewed.

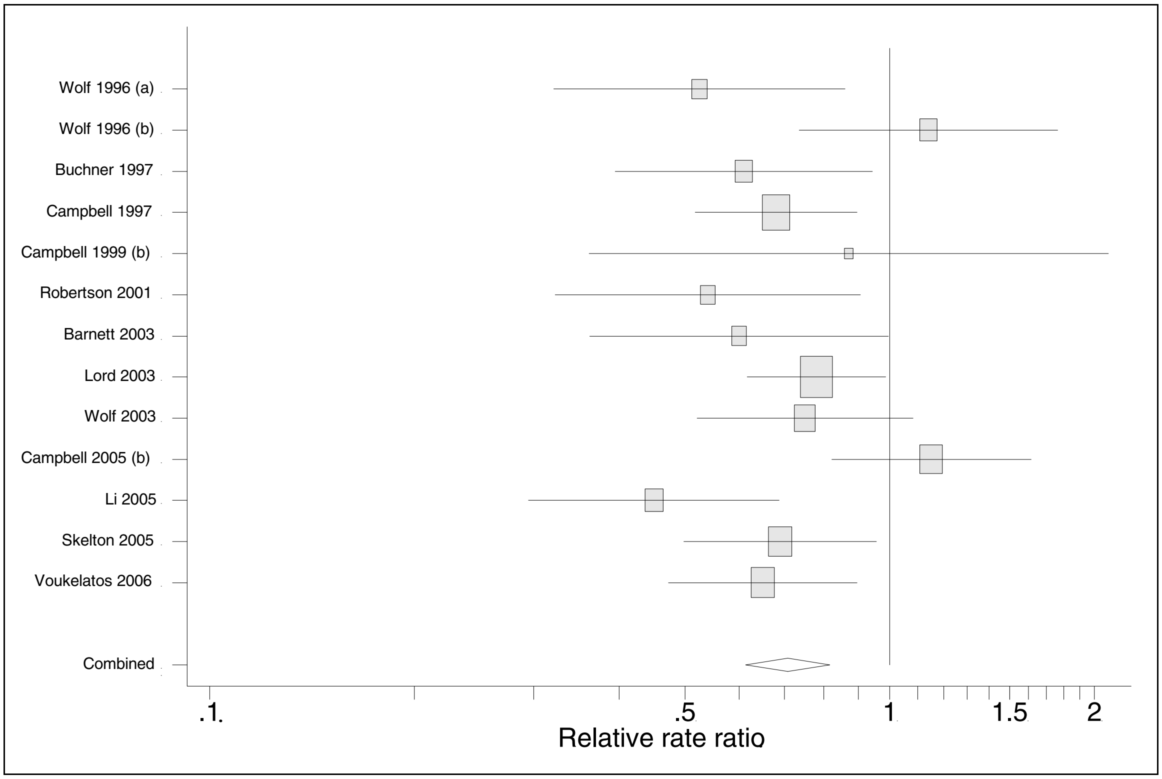
However, some RCTs have focused on physical activity as the sole intervention to prevent falls and fall injuries. As discussed below, these trials typically test a multi-modal exercise intervention involving some combination of aerobic (e.g., walking), muscle-strengthening, balance, and flexibility activities, or they have tested tai chi.

Rationale

Using the *Physical Activity Guidelines for Americans* Scientific Database and consultant suggestions, the subcommittee identified 8 systematic reviews or meta-analyses addressing physical activity and falls (70-77). When necessary, the subcommittee reviewed the original research papers referred to in the meta-analyses and reviews to ascertain study details regarding subject population and physical activity interventions.

The meta-analysis by Campbell and Robertson is the most recent analysis that addresses physical activity and falls (70). The authors employed stringent inclusion criteria for the analysis: 1) all studies were RCTs; 2) all participants were aged 60 years or older or had a mean age older than 70 years; 3) the majority of the participants lived independently in the community; 4) fall events were recorded prospectively; 5) follow up lasted at least 6 months; 6) at least 70% of the participants completed the trial; 7) all falls during the trial for at least 50% of the participants were included in the analysis; and 8) a relative rate ratio with 95% CI comparing the number of falls in the intervention group and the control group were recorded. Twelve physical activity trials met the inclusion criteria for the analysis (one of the trials compared 2 different exercise interventions to controls (78). The pooled rate ratio was 0.71 (95% CI 0.61 to 0.82; $P<0.001$), indicating that physical activity reduces risk of falls (see Figure G6.3 and Table G6.A3) (Table G6.A3, which summarizes these studies, can be accessed at http://www.health.gov/paguidelines/report/.) The trials included strength and balance training (79-85), computerized balance training (78), tai chi (78;86-88). One study included endurance training and/or strength training (89).

Figure G6.3. Exercise Interventions To Prevent Falls in Older Adults



Pooled rate ratio 0.71 (95% CI 0.61 to 0.82; *P*<0.001). Tests for heterogeneity Q = 21.49, *P*=0.044; I2 = 44%.

Source: Adapted with permission from Age and Ageing 2007;36 pp.656-62, Figure 2b. "Rethinking individual and community fall prevention strategies: a meta-regression comparing single and multifactorial interventions." Campbell A and Robertson M.

Figure G6.3. Data Points

Trial	Rate Ratio*	95% CI Lower Limit	95% CI Upper Limit	SE
Wolf et al., 1996 (a) (78)	0.525	0.321	0.86	0.138
Wolf et al., 1996 (b) (78)	1.14	0.733	1.76	0.262
Buchner et al., 1997 (89)	0.61	0.39	0.93	0.138
Campbell et al., 1997 (81)	0.68	0.52	0.90	0.097
Campbell et al., 1999 (b) (80)	0.87	0.36	2.09	0.441
Robertson et al., 2001 (84)	0.54	0.32	0.90	0.148
Barnett et al., 2003 (79)	0.60	0.36	0.99	0.161
Lord et al., 2003 (83)	0.78	0.62	0.99	0.094
Wolf et al., 2003 (88)	0.75	0.52	1.08	0.143
Campbell et al., 2005 (b) (82)	1.15	0.82	1.61	0.202
Li et al., 2005 (86)	0.45	0.30	0.70	0.102
Skelton et al., 2005 (85)	0.69	0.5	0.96	0.117
Voukelatos et al., 2007 (87)	0.65	0.47	0.89	0.107

Most of these trials and others were reviewed in a second systematic review by the same authors (90). The total number of participants in the 27 trials reviewed was 5,169. Four trials included women only and one study included only men. The majority of the studies involved independent older adults. One study included older adults living in retirement communities. A significant reduction in the number of all falls during the study was demonstrated in 6 of the 9 studies that included analysis of multiple falls. The reduction in the number of falls between intervention and controls ranged from 22% to 47.5%.

It should be noted that numerous trials have not shown a reduction in falls. Many fall prevention trials have been insufficiently powered. Numerous studies include too few subjects, have inadequate length of follow up or include subjects who are not at risk for falls. For this reason, many trials have not been successful at demonstrating an effect of physical activity on reducing falls (72;90).

Most of the interventions trials that have demonstrated a reduction in falls have included several exercise modalities: strength, balance training, exercises based on functional activities (e.g., chair stands, reaching, stair climbing), coordination activities (e.g., dance, ball games), walking outside or other endurance activities, and progression in the difficulty and complexity of the program. Currently, interventions with the most evidence include strength and balance training to reduce falls. One meta-analysis pooled and analyzed 4 trials that used a similar exercise intervention (the Otago Exercise Programme from New Zealand, which focuses on home-based strength and balance training) (76). The meta-analysis included 1,016 community dwelling women and men aged 65 to 97 years. The results from this study demonstrate a reduction in falls of 35% (95% CI 0.57 to 0.75). In addition, this analysis demonstrated a 35% reduction in the number of injurious falls (95% CI 0.53 to 0.81). Subjects aged 80 years and older benefited significantly more than did subjects aged 65 to 79 years of age.

Evidence also exists that tai chi exercise training programs provide benefit (75;77;86;87), although the evidence is inconsistent (77). Tai chi exercises consist of slow but continuous movements of all parts of the body incorporating elements of strength, balance, coordination, postural alignment, and concentration (77). All of these areas of fitness are related to risk of falls. To date, several studies examining tai chi have shown a reduction in falls in older adults (78;86;87). The reason for the success of these trials may be due to their study design in terms of size (all studies had more than 200 subjects) and duration (all studies lasted for 1 year or longer).

Pattern of Exercise

The frequency and duration of the exercise programs in the successful exercise trials vary. In the 9 positive exercise interventions (out of 13) analyzed in the recent meta-analysis by Campbell and Robertson (70), frequencies included 1 hour per week of center-based strength, balance, endurance and coordination instruction with home exercises encouraged (79), 1 hour 2 times per week of center-based strength, balance, endurance, and coordination instruction (83), 1 hour 3 times per week of center-based strength and/or aerobic training

(89), 30 minutes 3 times per week of home-based strength and balance with additional encouragement to walk for 30 minutes 2 or more times per week (81;84), 1 hour per week to 1 hour 3 times per week of tai chi (86), 45 minutes 2 times per week of center-based tai chi with daily home exercises encouraged (78), center-based strength, balance, flexibility and endurance program for 36 weeks for 1 hour a week, and the home-based Otago Exercise Programme 2 times a week for 30 minutes (85).

The falls prevention program from New Zealand — the Otago Exercise Programme — merits description, as it has been studied the most. The details of this program are outlined in an instructional review paper (91). Briefly, through several home visits, a trained instructor teaches an individualized, progressive, moderate-intensity lower body muscle strengthening exercises using ankle cuff weights in addition to balance exercises. Balance exercises progress from holding on to a stable support, such as furniture, to performing exercises independent of support. Exercises include: knee bends, backward walking, sideways walking, tandem stance and walk, heel walking, toe walking, and sit-to-stand. The participant is instructed to perform these activities 30 minutes 3 times per week and is also encouraged to walk outside for at least 30 minutes 2 or more times per week.

A few caveats of these results should be noted. First, the benefits continue as long as the programs are carried out (80) but there is no reason to believe that benefits would persist once the programs are stopped. In addition, the activities must be specifically designed for fall prevention. Less-specific exercise programs, such as brisk walking do not reduce falls. In fact, one program of brisk walking increased the fall rate (92). Also, high-intensity training in a frail population may increase musculoskeletal symptoms without decreasing falls (66). The intensity of most of the successful interventions would be considered moderate. Lower-intensity interventions do not seem to be of much value (93-95).

Sex, Age, and Race/Ethnicity

Far more women than men have participated in research studies on falls (69). However, it appears that men and women benefit equally from physical activity falls prevention programs (63;76). Although the sex of participants may not have a significant impact on success of intervention trials, age does. Exercise programs are most successful when they include subjects aged 80 years and older and/or include subjects who have a history of falling (70). This is most likely due to baseline impaired strength and balance arising from low levels of physical activity that underlie many falls experienced by elderly people, especially those aged 80 years and older. Currently, no data are available to ascertain whether response to physical activity and falls prevention differs by race or ethnicity.

Comparison to Current Guidelines

Current recommendations from the ACSM and the AHA include balance training for older adults at risk of falls as well as aerobic and strength training (68). In addition, guidelines for the prevention of falls from the American Geriatric Society also recommend physical activity, especially with balance training as one of the components (69). It should be noted that neither the ACSM/AHA nor the AGS guidelines provide recommendations for the frequency or duration of balance training.

The Otago Exercise Programme used in 4 intervention trials meets the ACSM/AHA recommendations, and this program has been shown to be successful at reducing falls in older community-dwelling people (76). Evidence also suggests that programs meeting just less than the ACSM/AHA recommendations (e.g., frequency of less than 5 days per week) also are successful at reducing falls (79;83;85). However, all of these programs still combine muscle strengthening and balance exercises in addition to walking. The results from the studies that focused on tai chi are more difficult to compare to the ACSM/AHA recommendations due to the nature of the activity, but clearly, balance is an important element of tai chi and several of the tai chi trials showed a reduction in falls (75;77;86;87).

Overall Summary and Conclusions

Regular physical activity has substantial health benefits. It is important to characterize the benefits in terms of preventing diseases and premature mortality, which is the purpose of most chapters of this report. It is also important to characterize the benefits in terms of the impact of physical activity on ability to perform the tasks of everyday life, which is the overarching purpose of this chapter. The Functional Health subcommittee focused on 3 questions pertaining to middle aged and older adults: (1) Does physical activity prevent or delay the onset of functional limitations and/or role limitations? (2) In adults with existing functional limitations and/or role limitations, does physical activity have a beneficial effect on functional ability and role ability? (3) Does physical activity reduce risk of falls and injurious falls?

Scientific evidence pertaining to each of these questions was systematically sought and reviewed. Based upon this evidence, the subcommittee's main conclusions are:

- Strong, consistent observational evidence indicates that mid-life and older adults who participate in regular physical activity have reduced risk of moderate or severe functional limitations and role limitations. Active mid-life and older individuals — both men and women — have approximately a 30% lower risk of developing moderate or severe functional limitations or role limitations compared with inactive individuals. The evidence of benefit is strong for aerobic activity, but limited for other types of activity (muscle-strengthening, balance, and flexibility activities).

- In older adults with existing functional limitations, moderate, fairly consistent evidence indicates that regular physical activity is safe and has a beneficial effect on functional ability. The evidence of benefit is moderate for physical activity involving both aerobic and muscle strengthening activities, but evidence is limited for any single type of activity used alone. Further, evidence to conclude that physical activity improves or maintains role ability is currently limited.

- In older adults at risk for falls, evidence is strong that regular physical activity is safe and reduces falls. The evidence of benefit is strong for physical activity programs that emphasize both balance training and muscle-strengthening activity, and also include some aerobic activity, especially walking. Moderate evidence also indicates that tai chi exercise programs provide benefit, although the data are inconsistent. In older adults without substantial functional limitations and at low risk of falls, limited evidence indicates that physical activity reduces fall risk. Further, limited evidence suggests that physical activity reduces risk of injurious falls (e.g., fractures) in older adults.

In addition, previous reviews of scientific evidence have established that physical activity in middle-aged and older adults improves physical fitness and physiologic capacity (aerobic, strength, and balance) even into advanced age (3;96).

In summary, physical activity can help prevent or delay the onset of functional and/or role limitations, improve functional ability, and reduce falls. Because older adults have the lowest physical activity participation rates of any age group and have the highest risk of disability, increasing physical activity in older adults is an important public health goal.

Research Needs

It is important that future research on older adults and physical activity develop a consensus around standardized and meaningful outcomes for assessing functional health and disability. Developing universally agreed-upon outcome measures in this area will greatly assist future evaluations of research. The research to date demonstrates that moderate-intensity, multi-modal interventions appear to have benefit. However, it is not known whether: 1) single-mode interventions (e.g., walking alone) are equally effective; 2) a threshold or dose effect of physical activity exists that affects functional health; 3) higher intensity interventions are more or less effective than moderate-intensity activity and 4) these interventions are equally effective in understudied populations.

The impact of power training on improving functional ability in older adults has been addressed in a few trials and shows promise (60;97) and is addressed in greater detail in ***Part G. Section 5: Musculoskeletal Health.*** Future research should address more fully whether power training is effective, feasible, and safe for older adults with functional limitations. Most importantly, due to the high economic costs associated with disability, future research needs to focus on large-scale well-designed trials to ascertain whether physical activity programs can prevent disability and role limitations as people advance into old age.

With respect to falls, although existing research provides strong evidence that physical activity programs decrease fall risk, it is still not clear which programs are most suitable for which population groups. For example, is tai chi better for a younger population and an individualized home-based program more suitable for those who are older? Similar to

Question 2, it appears that moderate intensity multi-modal interventions appear to have benefit. However, we do not know whether there is a threshold or dose effect of physical activity on reducing falls or whether higher-intensity interventions are more or less effective. We also do not know whether interventions are equally effective in across all population groups. To date, only a few research studies have addressed whether injurious falls are reduced with physical activity programs in older adults (80). Although fractures are discussed in detail in ***Part G. Section 5: Musculoskeletal Health,*** it deserves mentioning here that an RCT with sufficient power is needed to assess whether physical activity can reduce fractures as an endpoint. This is an important research topic because 90% of hip fractures result from falls.

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