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Literature Review

Updating the Evidence for Physical Activity: Summative Reviews of the Epidemiological Evidence, Prevalence, and Interventions to Promote "Active Aging"

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Abstract

Purpose of the Study: There is a global imperative to increase awareness of the emerging evidence on physical activity (PA) among older adults. "Healthy aging" has traditionally focused on preventing chronic disease, but greater efforts are required to reduce frailty and dependency and to maintain independent physical and cognitive function and mental health and well-being.
Design and Methods: This integrated review updates the epidemiological data on PA, summarizes the existing evidence-based PA guidelines, describes the global magnitude of inactivity, and finally describes the rationale for action. The first section updates the epidemiological evidence for reduced cardiometabolic risk, reduced risks of falls, the burgeoning new evidence on improved cognitive function and functional capacity, and reduced risk of depression, anxiety, and dementia. This is followed by a summary of population prevalence studies among older adults. Finally, we present a "review of reviews" of PA interventions delivered from community or population settings, followed by a consideration of interventions among the "oldest-old," where efforts are needed to increase resistance (strength) training and balance.
Results: This review identifies the global importance of considering "active aging" beyond the established benefits attributed to noncommunicable disease prevention alone.
Implications: Innovative population-level efforts are required to address physical inactivity, prevent loss of muscle strength, and maintain balance in older adults. Specific investment in healthy aging requires global policy support from the World Health Organization and is implemented at the national and regional levels, in order to reduce the burden of disease and disability among older adults.

Key Words: Physical activity, Older adults, Evidence, Integrated review

The global increase in the aging population places increased pressures on health systems and services for older adults. Demographic trends over the next three decades project that the global numbers of adults aged 65 years and older will double to around two billion by 2050 (World Health Organization [WHO], 2015). Of these older adults, 80% of the increase will occur in low-middle income countries (WHO, 2015). Furthermore, life expectancy is increasing at a similar rate in less developed countries, and by 2050, the global numbers of adults aged 80 years and older will be 268 million in less developed countries, compared with 124 million in developed countries (United Nations Department of Economic and Social Affairs, Population Division, 2013). These demographic trends will have an impact on resources to manage the resultant increase in chronic disease, treat falls-related injuries, and manage the costs of caring for older adults. One of the most important approaches to delay the morbidity associated with aging is to increase physical activity (PA) among older people.

The concept of Active Aging is more than a decade old (Kalache, Aboderin, & Hoskins, 2002), and although it is well established in the policy framework in some countries, it remains less well implemented in many nations. It describes the processes of "healthy aging," resulting in reduced rates of chronic disease, more productive older years, and greater cognitive and functional capacities to carry out tasks and to participate and enjoy social and cultural life (WHO, 2002). Among the behavioral and lifestyle factors, PA is the most important determinant of "active aging" and has a major role in improving the quality of life, in reducing disability, and in the "compression of morbidity" in later life (Crimmins, 2015; Kalache et al., 2002). For older adults, PA includes large muscle "aerobic activities," such as walking, cycling, and many recreational activities and sports. In addition, important dimensions of PA include muscle strength and balance training, which also have a major role in health promotion and disease prevention in older adults (Garber et al., 2011).

As a component of both primary and tertiary prevention, PA is an important component of the World Report on Ageing and Health 2015 (WHO, 2015). This article provides an update of the health consequences of inactivity in older adults, with an increased emphasis on muscle strengthening and balance training. We then summarize PA prevalence in old age and integrate epidemiological evidence and prevalence data, which support the PA guidelines (PAGs). Finally, we review the evidence on the effectiveness of community-based and clinical interventions to increase activity among older adults and, as a special group, in the frail elderly adults. In general, systematic reviews were used in all sections of this article, with reviews of existing reviews or de novo summaries developed to support the role of PA in healthy aging.

The overall aim of this article is to update the rationale for increasing PA for all older adults, from a practitioner and policy perspective, and to provide new guidance on benefits of PA and on the types of PA required for health.

The Range of Benefits of PA in Older Adults

Epidemiological evidence is used to characterize the health consequences of physical inactivity for population health. Overall, physical inactivity is the fourth leading risk factor contributing to deaths and the burden of disease globally ranking ahead of overweight or obesity (Lee et al., 2012). A summary of the range of health benefits specifically for older adults is shown in Figure 1, which includes effects on improving functional status, psychological status and well-being, and social benefits, as reviewed in the U. S. distillation of evidence for the health benefits of PA (U.S. Health and Human Services, 2008). The epidemiological evidence for these benefits has accumulated over several decades,

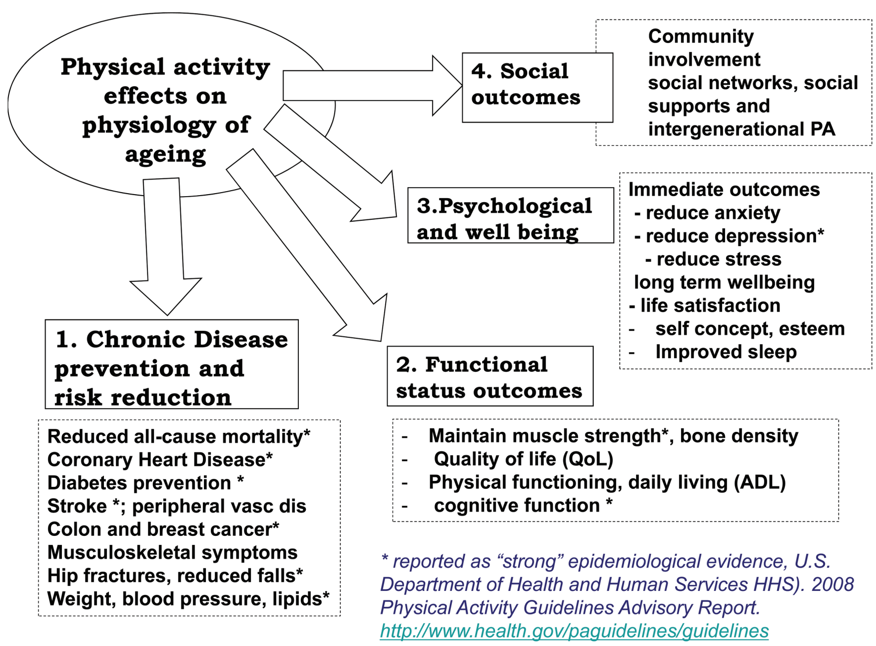

Figure 1. A conceptual framework for the benefits of physical activity in older adults. *Reported as "strong" epidemiological evidence, U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines Advisory Report. Retrieved from http://www.health.gov/paguidelines/guidelines

with the newest evidence focusing on neurological health and psychosocial and mental well-being.

The general population evidence on PA benefits for reducing all-cause mortality risk, preventing cardiovascular disease and diabetes, and evidence on benefits on lipid levels, hypertension and reducing the risks of breast and colon cancer, also apply to older adults (Batty, 2002; Chodzko-Zajko et al., 2009; Vogel et al., 2009). Some initial meta-analytic evidence suggests that protective benefits accrue for older adults at levels of PA well below current recommendations (Hupin et al., 2015), but this needs further examination in those with and without comorbidity. Further, there is evidence that muscle strength and resistance training may also contribute to noncommunicable disease (NCD) prevention, for example through glycemic control, independent of aerobic activities (Chodzko-Zajko et al., 2009).

PA reduces the risk of developing stroke in older adults of differing age groups and diverse populations (Goldstein et al., 2006; Wannamethee & Shaper, 2014). Two meta-analyses estimated that the relative risk reduction for all forms of stroke was 11%–15% for moderate PA (Diep, Kwagyan, Kurantsin-Mills, Weir, & Jayam-Trouth, 2010; Wendel-Vos et al., 2004) and 19%–22% for vigorous PA; this relationship was stronger for men, with only vigorous activity being protective among women (Diep et al., 2010). The benefits of moderate-intensity aerobic activity are well established in the prevention of type 2 diabetes, blood pressure, and other cardiometabolic diseases (Chodzko-Zajko et al., 2009). Emerging evidence now supports similar benefits for muscle strength training, especially in maintaining or increasing muscle mass, which attenuates the metabolic and functional consequences of muscle loss with aging, known as sarcopenia (Grøntved, Rimm, Willett, Andersen, & Hu 2012; Grøntved et al., 2014).

One review (De Rezende, Rey-López, Matsudo, & do Carmo Luiz, 2014) has examined the separate behavior of prolonged sitting time, a sedentary behavior independent of PA, among adults aged 60 and older and noted an increased association with all-cause mortality, metabolic syndrome, and waist circumference. “Too much sitting” may add to the risk of NCD posed by low PA, but as this is a new area of epidemiology, the evidence base remains limited, particularly among older adults.

PA is associated with biomarkers of aging; active older adults show less telomere (end chromosomal) shortening and fragmentation, compared with their inactive counterparts, even in twin studies (Kaliman et al., 2011; Ludlow et al., 2008). This suggests that active adults may have reduced oxidative stress, or positive epigenetic changes induced by PA (Kaliman et al., 2011). A recent randomized controlled trial (RCT) suggested that this might be attributable to reduced sitting time, instead of only increased PA (Sjögren et al., 2014). Although this study involved a very small sample and hence may be subject to random error, it suggests that reducing sedentary behavior as well as increasing PA may contribute to healthy biological and functional aging (Chodzko-Zajko et al., 2009).

Emerging evidence suggests that PA can improve cognition in people without dementia, reduce the incidence of dementia, and improve health among people with existing dementia (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008; Blondell, Hammersley-Mather, & Veerman, 2014; Sofi et al., 2011). There is increasing evidence from epidemiological and clinical studies that PA can improve cognitive function (Paterson & Warburton, 2010); further, this evidence is biologically plausible, given evidence of cognitive function improvement and neuroplasticity from exercise animal studies, and preliminary evidence of the biochemical mechanisms and pathways (Ahlskog, Geda, Graff-Radford, & Petersen, 2011; Bherer, 2015; Blondell et al., 2014; Sofi et al., 2011). Additionally, low muscle mass and muscle strength have each been linked to cognitive impairment or dementia and brain atrophy in cross-sectional (Burns, Johnson, Watts, Swerdlow, & Brooks, 2010) and prospective cohort studies (Boyle, Buchman, Wilson, Leurgans, & Bennett, 2009). Clinical trials of both aerobic and resistance training show positive effects on executive function, attention, and processing speed, with inconsistent evidence for memory and other domains (Scherder et al., 2014). Further, among those who exercise, there is clinical and neuroimaging evidence of larger hippocampal volumes (Erickson et al., 2011), better cerebrovascular flow, and better performance of functional MRI-defined cognitive tasks (Ahlskog et al., 2011). More recently, it has been noted that motor fitness (e.g., movement speed, balance, and motor co-ordination) is also associated with cognitive performance but differentially related to cognitive processes than physical measures of fitness (Voelcker-Rehage, Godde, & Staudinger, 2011).

Recent reviews point to a 28% reduced risk of developing dementia among the physically active older adults (Ahlskog et al., 2011; Blondell et al., 2014). It appears that physical inactivity is the most important preventable risk factor for Alzheimer’s dementia, with the population-attributable fraction estimated to be around 20% (Norton, Matthews, Barnes, Yaffe, & Brayne, 2014). This implies that approximately 10 million new cases of Alzheimer’s dementia could be prevented each year globally if older adults met PA recommendations (Norton et al., 2014). For tertiary prevention evidence, 16 trials show improvements in physical function among people with Alzheimer’s disease who are prescribed exercise (Blankevoort et al., 2010). Other neurological conditions, including the risk of developing Parkinson’s disease, are typically 20%–30% lower among older adults who are physically active (Chen, Zhang, Schwarzschild, Heman, & Ascherio, 2005; Thacker et al., 2008); again, tertiary prevention trials have shown benefits of exercise interventions for people with established Parkinson’s disease, with benefits to strength (Lima, Scianni, & Rodrigues-de-Paula, 2013), walking, motor control, and balance (Shu et al., 2014).

Maintaining functional status is an important part of active aging and reducing age-related morbidity; it facilitates independent living, improves quality of life, and reduces health care costs (Chodzko-Zajko et al., 2009; Nelson et al., 2007). A systematic review concluded that PA reduces the age-related decline in functional capacity and maintains muscle strength and mass among adults aged 65–85 years (Paterson & Warburton, 2010). A 50% reduction in the relative risk of developing functional limitations or disability was reported among those participating in moderate-intensity PA (Paterson & Warburton, 2010, Tak, Kuiper, Chorus, & Hopman-Rock, 2013). Among older groups (aged 70–75 years), functional status may be preserved with even lower amounts of PA. It remains less clear whether progressive resistance training alone can influence functional performance, although the Cochrane collaboration review reported significant independent effects of resistance training on strength and on capacity to perform activities of daily living (Liu & Latham, 2009). Related to these outcomes, there are consistent associations between PA and quality of life or vitality measures in older adults (Klavestrand & Vingård, 2009; Motl & McAuley, 2010), but findings were stronger in cross-sectional than in longitudinal studies, with too few interventions to clearly assess whether the associations are causal (Voukelatos et al., 2015).

A major source of morbidity and health costs among older adults is the increased rate of falls, injuries, and fractures. The primary risk factors for falls, including osteopenia, poor balance, and muscle weakness, are all modifiable by appropriate exercise (Chodzko-Zajko et al., 2009). Targeted interventions to improve balance and muscle strength can reduce falls risk (Howe, Rochester, Neil, Skelton, & Ballinger, 2011). There is consistent controlled trial evidence that structured exercise programs reduce rates of falls. Multicomponent community-based trials show a 29%–32% reduced risk of falls (Gillespie et al., 2012; McClure et al., 2005) and a 66% reduced risk of falls-related fracture. By contrast, the evidence for falls prevention for people in hospital and in health care settings is less clear for PA and exercise programs (Cameron et al., 2012). It is important to note that isolated walking interventions have no clear benefits in falls prevention. By contrast, as a single activity, tai chi was found to be efficacious in falls prevention (Howe et al., 2011). Weight bearing aerobic, high impact and resistance training can improve bone mineralization, resulting in maintained or improved bone density in older women (Chodzko-Zajko et al., 2009; Howe et al., 2011) to prevent osteoporosis and falls-related injuries.

Mental health and social benefits among older adults are attributed to PA. There is some evidence that aerobic PA can reduce symptoms of depression and possibly reduce anxiety and improve mental health among older adults (Bridle, Spanjers, Patel, Atherton, & Lamb, 2012; Netz, Wu, Becker, & Tenebaum, 2005; Windle, 2014; Windle, Hughes, Linck, Russell, & Woods, 2010). Higher intensity resistance training is also effective in reducing depression symptoms (Chodzko-Zajko et al., 2009). For the less well-defined measure of "well-being," intervention evidence is less clear (Windle, 2014; Windle et al., 2010). There is some evidence for social benefits of PA, but confined to individual measures of confidence, mastery, and self-esteem and to reported social interaction, reduced isolation, and increased community engagement (McAuley et al., 2000). The limited literature does suggest the possibility of a bidirectional relationship between PA and both social networks and relationships, as well as social capital (McNeill, Kreuter, & Subramanian, 2006), with active older adults more engaged in their communities, but conversely, well-integrated communities also fostering PA.

Physical Activity Guidelines: What Proportion of Older Adults Is Meeting Them?

PAGs (or recommendations) distil the epidemiological evidence into behavioral guidance for professionals and for the general population. In 2010, the WHO released PAGs for adults aged 65 years and older. The guidelines comprised specific recommendations for strength and balance or flexibility, as well as for aerobic (large muscle) activity throughout the week (Table 1). There are slight differences in country-specific interpretations of the PAGs for older adults, which are shown in the right hand column of Table 1. Differences include mention of prolonged sitting time (UK only), omission of the "10-minute threshold" for health-enhancing activity (Australia), and slight differences in the interpretation of 150 minutes/week of activity. The global PAGs are designed to provide global guidance for all older adults in all countries; some adaptation may be required for special populations, such as for older adults with specific disabilities or with specific chronic health problems (WHO, 2010a).

National or regional PA surveillance systems are used to monitor the proportion of adults meeting the recommended amounts of PA for health. Usually self-report questions are asked in surveillance, as different objective measurement instruments provide different population estimates and still remain to be standardized for surveillance (Pedišić & Bauman 2015). There are infrequent cross-national monitoring surveys of reported PA to compare proportion of older adults meeting the PA levels recommended for health. For this review, two such international surveys were analyzed, the World Health Survey (WHS, 2002) collected in around 70 countries between 2002 and 2004 and the Study on Global AGEing and adult health (SAGE, 2007–2010 [WHO, 2010b]) survey in major transitional countries. The country estimates for people meeting the 150 minutes/week guideline were examined for older adults, and the median estimates of "meeting the PAGs" for the 70 countries in the WHS are shown in Table 2. There are substantial increases in the proportions not meeting the PAGs after age 60, with

Table 1. Physical Activity Guidelines (PAGs) for Older Adults (65 Years and Older), WHO 2010a

WHO PAGs 2010 for adults 65 years and older	Reflection on the recommendations in the UK, Canadian, and Australian PAGs for older adults 2011–2013
Total volume of PA for older adults	Was described as 30 min/day (most days in AUS; revised to 150 min/week in 2014)
Older adults should do (a total of) at least 150 min of moderate-intensity aerobic PA per week or do ≥75 minutes of vigorous-intensity aerobic PA or an equivalent combination of moderate- and vigorous-intensity activity	Described as 150 min/week (UK, CAN) or in equivalent combinations of moderate and vigorous minutes/week
Minimum duration of activity	No longer any mention of 10-min minimum (AUS)
Aerobic activity should be performed in sessions of at least 10-min duration	Mention minimum bout length, 10 min (CAN, UK)
Upper limit—How much additional activity confers benefit?	Carry on vigorous activity if lifelong (provided risks are considered; AUS)
For additional health benefits, older adults can increase their activity to 300 min per week, or engage in 150 min of vigorous-intensity aerobic PA per week, or an equivalent combination of moderate- and vigorous-intensity activity	More PA provides greater benefits (CAN) Should minimize time spent in prolonged sitting (UK); generic recommendation
Falls prevention activity	Older adults should do a range of PA including fitness, strength, balance, and flexibility (AUS)
PA to enhance balance on 3 or more days per week. Muscle-strengthening activities, involving major muscle groups, should be done on 2 or more days a week.	Those with poor mobility should do balance training to prevent falls (CAN) At risk of falls, balance exercise two times/week (UK) Add muscle and bone strengthening 2 days/week (CAN, UK)
Activity for older adults with chronic disease	Start with any amount if inactive or have health problems (reflected in all guidelines; UK, AUS)
When older adults are limited in their PA due to health conditions, they should be as physically active as their abilities and conditions allow	

Notes. Adapted from WHO, 2010a. Retrieved December 2014, from www.who.int/dietphysicalactivity/factsheet_olderadults/en/
With input from (i) the Canadian PAGs 2010 (Public Health Agency of Canada, 2011; Warburton, Charlesworth, Ivey, Nettlefold, & Bredin 2010). Retrieved from http://www.csep.ca/CMFiles/Guidelines/CSEP_Guidelines_Handbook.pdf). (ii) the UK Stay Active report 2011. Retrieved from http://www.nhs.uk/Livewell/fitness/Documents/older-adults-65-years.pdf; and (iii) the Australian older adult PAGs 2014. Retrieved January 2015, from http://www.health.gov.au/internet/main/publishing.nsf/Content/phd-physical-rec-older-guidelines
PA = physical activity; PAG = physical activity guideline.

Table 2. Data From the World Health and SAGE Surveys, Median Prevalence of Not Meeting the Minimum Aerobic PAGs by Age Group

	Age group (years)					
	18–29	30–44	45–59	60–69	70–79	Older than 80
World Health Survey[a] not meeting PAGs (%)						
Males, median prevalence[a]	7.0	8.8	8.6	**18.8**	**29.5**	**42.1**
Females, median prevalence	12.3	10.7	14.0	**24.5**	**38.4**	**54.6**
SAGE surveys[b], not meeting PAGs (%)						
Males, median prevalence	9.2	12.8	17.7	**21.9**	**34.4**	**51.1**
Females, median prevalence	22.8	19.5	17.5	**23.4**	**36.4**	**58.9**

Notes. Bold values represent data of older adults.
PAG = physical activity guideline; SAGE = Study on Global Ageing and Adult Health
[a]World Health Survey median prevalence by age group from the n = 70 participating countries.
[b]SAGE countries: China, Ghana, India, Mexico, Russia, South Africa (WHO, 2010b).

marked increases after age 80 years, where nearly half the populations did not meet the minimal threshold for health. The WHS used the generic International Physical Activity Questionnaire (IPAQ) short measure (Craig et al., 2003), which allows all domains of self-report activity work, leisure, transport, and domestic PA to be included to reach the guidelines, so that this may over-report true levels of activity; however, relative differences by age group are likely to be valid. Similar increases in the median estimates of the proportions not meeting the guidelines with increasing age are seen in the five-country SAGE survey. The policy implications of these data are that inactivity increases substantially with age across countries, based on "aerobic activity" measures.

A recent systematic review examined sedentary behaviors in older adults and reviewed data from 22 studies (Harvey, Chastin, & Skelton, 2015). This review noted the consistent increase in sedentary time with increasing age, even when considering those with and without comorbidity, with sitting time averaging 9+ hours/day among older adults. This suggests the need to consider reducing sedentary time, alongside efforts to increase PA.

A key challenge in the area of surveillance is the omission of major dimensions of PA related to strength training and balance. These are rarely assessed in monitoring surveys, and when they are, show much lower rates of meeting the guidelines than the aerobic measures in Table 1. For example, the U.S. monitoring data show that around 20% of older adults meet the strength training frequency and the aerobic activity 150 minutes guideline (Centers for Disease Control and Prevention [CDC], 2006, 2013), and rates are similar in the few countries that assess this; these are much lower than the proportion meeting the 150 minutes of moderate-intensity PAG alone. Similarly, scant data exist on participation in specific balance exercise; in Australia only 6.2% reported to do so (Merom et al., 2012). These important health-related dimensions are seldom monitored, and as a result, are often omitted from public health estimates for assessing "sufficiently active," or from strategies to increase PA, or in clinical advice to older adults.

Review of Community Interventions to Promote PA in the Elderly Adults

The majority of older people (90%–95%) prefer to remain in their own homes and communities even if that means living alone (National Institute on Aging, 2011). Identifying best practice strategies to increase PA among community-dwelling older adults is important to maintain functional independence. This section reviews published systematic reviews of interventions to promote PA among community-dwelling older adults aged 65 or older to identify gaps in knowledge in assessing their effectiveness. Medline searches were complemented by CINAHL and Cochrane database. Keywords comprised "intervention studies" or "promotion" or "health promotion" AND "physical activity" or walking or exercise or physical fitness or aerobic fitness or sports or muscle strength or resistance training or physical training or balance or postural balance AND limiting the search to adults 65 years old and beyond, English language, years 1990–2015, human and review articles. Inclusion criteria were reviews that summarized primary intervention studies and reported on measures of adherence or PA change as main outcomes. This search yielded 172 review articles, 159 were excluded based on title and abstract, of those, 90% reviewed the effect of PA or exercise on various health outcomes. Full text of 13 review articles were assessed, and we excluded additional systematic reviews that focused on settings such as primary care interventions (Neidrick, Fick, & Loeb, 2012) or home-based versus center-based interventions (Ashworth, Chad, Harrison, Reeder, & Marshall, 2005) and five narrative reviews, for example, traditional and recent approach to promote balance (Granacher, Muehlbauer, Zahner, Gollhofer, & Kressig, 2011). The reviews were summarized by their scope, inclusion criteria and age of population, setting, the PA target of the intervention or approaches, if target was not specified, and their effectiveness. When reviews included interventions that deliver to younger populations (younger than 65 years), we summarized only those that delivered to older groups, when possible (King, Rejeski, & Buchner, 1998; van der Bij, Laurant, & Wensing, 2002). Six systematic reviews or meta-analyses were identified in the past 20 years (Supplementary Table).

Initially, interventions were mostly based in community centers. The proportion of home-based interventions increased over time; for example, in the review by Chase (2015) covering the period 2000–2012, half of the interventions were home based. The PA targets in early reviews mostly focused on planned (structured) sessions of aerobic activity or muscle strengthening; fewer involved multimodal activities, such as balance or functional capacities (King et al., 1998; van der Bij et al., 2002). The promotion of walking or lifestyle PA as stand-alone interventions comprised 35% of the RCTs delivered only to older population in the period 1960–2000 (Conn, Minor, Burks, Rantz, & Pomeroy, 2003). It is unknown whether walking promotion increased over times as the PA target was not systematically reported in the most recent reviews by Chase, which focused on program-related moderators.

In terms of effectiveness, earlier reviews typically assessed attendance at program sessions, which was high in this population (>70%), with few primary studies reporting reported changes in PA or intervention effect sizes (ESs). However, in intervention studies where changes were reported, 50% also observed changes in PA in the control groups (van der Bij et al., 2002). The second review by Conn that was limited to older adults found that slightly more than half of the interventions (58%) showed significant between-group effects. The meta-analytic ES was modest, ES = 0.26 (Conn, Valentine, & Cooper, 2002), a value similar to the ES = 0.18 obtained in a more recent meta-analysis; this approximates to an increase of 73 minutes/week more in intervention over control participants (Chase, 2015). Successful interventions used mailed or audiovisual components and used behavioral theory and motivational approaches (Chase, 2015). Importantly, the effects of moderate-intensity and prescribed exercise were stronger than interventions that promoted low-intensity PA or had no prescription. In all other interventions, no effect over control was detected, with the exception of one walking intervention that reported significant effect in favor of control. The magnitudes of changes in PA were seldom reported in interventions in this review.

The superiority of center- versus home-based approach was discussed in three reviews; two found that the effects of home-based interventions were similar to that of center-based interventions (Chase, 2015; van der Bij et al., 2002), whereas Conn and colleagues (2002) indicated that center-based interventions had greater effects compared with home-based interventions (ESs 0.47 vs 0.24), but without controlling for intervention duration. The majority of interventions reviewed were short term (<6 months), and the differences between these two approaches were small, yet in "real world" settings, there is a substantial decline in attendance at center-based classes for seniors (Ecclestone, Myers, & Paterson, 1998; van der Bij et al., 2002).

Overall, there were some methodological issues overlooked in these reviews. First, reports of attendance rate did not categorize this outcome using the intention-to-treat principle and may have overestimated program effectiveness. Second, the measurement tools used were reported only in the review by Chase (2015), and may have omitted measures of specific intervention components. Third, the review by Chase in 2015 did not consider participants' baseline PA levels. Those who are physically inactive but hard to reach may demonstrate greater scope for PA change. The performance of interventions against public health guidelines was seldom reported. Finally, limited consideration was given to the moderating effect of interventions performed in diverse environments and targeting diverse socioeconomic or disadvantaged groups.

The limitation of this summary is its focus on systematic reviews of primary trials. It lacks reference to "best practice" programs and recommendations developed by organizations such as the CDC Taskforce on Community Preventive Services or the U.S. National Council on Aging. There are several effective programs and increasing evidence from translational research for successful community-based interventions. For example, scaling up PA programs through YMCA-related settings in the United States identified factors associated with uptake; these included professional and organizational support, program adaptations, and delivery mechanisms (Petrescu-Prahova, Belza, Kohn, & Miyawaki, 2015).

As the intervention field grows, we have highlighted areas for improvement, including measures used, evaluation methods for assessing program effectiveness, and accumulating better evidence of the effects of scaling programs up to the population level.

PA Interventions for the Oldest-old and Frail Adults

Frailty may be defined as a state of increased vulnerability resulting from age-related decline in reserve and function across multiple physiologic systems, attenuating the ability to cope with acute and chronic stressors, resulting in loss of homeostasis (Xue, 2011). Although many variations have emerged over the years, frailty has been operationally defined as meeting three out of five phenotypic criteria indicating compromised function: low grip strength, low energy, slowed waking speed, low PA, and/or unintentional weight loss, and "prefrailty" as meeting one or two criteria (Fried, Tangen, & Walston, 2001). Although frailty may occur at younger ages, the majority of the literature focuses on the demographic group at highest risk, the oldest-old (older than 85 years). Given the global trends in aging, there are advantages to addressing physical inactivity in this group, with a particular focus on addressing age- and disease-related disuse and loss of muscle strength and function, the hallmark of sarcopenia.

Barriers and goals for PA vary markedly across the life span, are particularly relevant in the most inactive segment of the population, the oldest-old and frail elderly adults, for whom low PA levels form part of the definition (Baert, Gorus, Mets, Geerts, & Bautmans, 2011; Fried et al., 2001). Although attitude toward PA and access to safe and appropriate venues or providers are always important (Franco et al., 2015), in the oldest-old and frail adults, individual ability to exercise must also be addressed, as the physical capacity to safely engage in activity is critical to participation, even when attitude and access are not limiting factors.

Many reviews and position statements support the benefits of PA for function, chronic disease outcomes, and mortality benefits in older adults, and these functional benefits extend to frail elders (Chou, Hwang, & Wu, 2012; de Labra, Guimaraes-Pinheiro, Maseda, Lorenzo, & Millan-Calenti, 2015; Theou et al., 2011).

The physical capacities most relevant to mobility impairments and independence in this group are muscle strength and power (Cruz-Jentoft et al., 2014) and balance, although including aerobic activity (walking) has been shown to improve mobility impairment (inability to walk 400 m independently) in community-dwelling elders with pre-existing deficits on the Short Physical Performance Battery (SPPB; Pahor et al., 2014). Recent large-scale trials affirm the benefits of multicomponent interventions to increase PA, strength, and balance on objective measures of frailty, compared with "successful aging" controls (Cesari et al., 2015, de Labra et al., 2015).

Given the centrality of weakness to the definitions of frailty (Fried et al., 2001; Liu & Fielding, 2011), PA and exercise programs in the oldest-old have often emphasized resistance training (also called strength training or weight lifting) as a direct antidote for sarcopenia (Chin, van Uffelen, Riphagen, & van Mechelen, 2008; Peterson, Sen, & Gordon, 2011). Resistance training interventions, at moderate-to-high intensity, have been shown to improve sarcopenia and functional status (Liu & Latham, 2011; Valenzuela, 2012), bone density (Kemmler, Haberle, & von Stengel, 2013), cardiometabolic health (Kay & Fiatarone Singh, 2006; Sagar et al., 2015; Yang, Scott, Mao, Tang, & Farmer, 2014), mental health and cognitive impairment (Chung, Thilarajah, & Tan, 2016; Gates, Fiatarone Singh, Sachdev, & Valenzuela, 2013; Heyn, Johnson, & Kramer, 2008; Silveira et al., 2013; Windle et al., 2010), hip fracture (Fiatarone Singh, 2014; Singh et al., 2012), among others. Robust outcomes for resistance training interventions have been linked to higher intensities (Raymond, Bramley-Tzerefos, Jeffs, Winter, & Holland, 2013; Steib, Schoene, & Pfeifer, 2010), supervision, and progression in resistance training (Gordon, Benson, Bird, & Fraser, 2009). Notably, aerobic capacity improves after isolated resistance training in older adults, because strength and muscle mass contribute to aerobic capacity, and thus resistance training may subsequently result in increased ability to engage in endurance activities like walking. For example, resistance training has been shown to increase habitual PA level in frail nursing home residents (Fiatarone Singh et al., 1994) without any direct promotion of, or change in access to, other activities, but the intensity of resistance training remains important (McGinley, Armstrong, Boule, & Sigal, 2015; Schoenfeld, Wilson, Lowery, & Krieger, 2014; Thiebaud, Funk, & Abe, 2014). By contrast, balance training alone does not improve strength or aerobic capacity, and aerobic training alone (most commonly walking) does not generally improve balance or strength.

These observations lead to clear practice and policy implications. For very frail adults who have minimal ability to walk safely or who are completely nonambulatory, seated resistance training under supervision is the most feasible exercise modality and should be the first activity recommended. Once standing is possible, it is important that the frail individual can avoid falls and injuries, and thus standing balance exercises can be added to resistance training. Independent walking requires sufficient muscle strength and balance to carry one's body weight through space, and once this threshold is reached, it is then important to enhance aerobic capacity so that walking can be maintained over clinically relevant distances. By contrast, mild-to-moderately frail adults, such as those in the structured LIFE study of mobility-impaired adults aged 70–89 years (Pahor et al., 2014), may safely undertake all three modalities of exercise (strength, balance, and walking) simultaneously with proven benefit for incident mobility disability. Unstructured, unsupervised PA recommendations have generally not been shown to improve mobility or function in frail adults. There is some support from a systematic review that exercise interventions in frail elders that combine strength, balance, training, and endurance may offer benefits in terms of function, mobility, falls prevention, and strength (Cadore, Rodriguez-Manas, Sinclair, & Izquierdo, 2013), but the data are mixed and other reviews suggest that such multicomponent programs are heterogeneous in their efficacy for functional improvements in frail elders (Gine-Garriga, Roque-Figuls, Coll-Planas, Sitja-Rabert, & Salva, 2014), although effective in community-dwelling elders with early mobility impairment (Pahor et al., 2014).

Balance training reduces fear of falling and improves mobility and balance in older adults at high fall risk (Sherrington, Tiedemann, Fairhall, Close, & Lord, 2011), whereas isolated resistance training does not consistently improve balance (Orr, Raymond, & Fiatarone Singh, 2008). However, the best interventions to prevent falls and reduce injuries and fractures (El-Khoury, 2013) are seen after programs of combined resistance and balance training (Sherrington et al., 2011; Thomas, Mackintosh, & Halbert, 2010). The promotion of moderate- or vigorous-intensity aerobic activity typically through walking to older adults should consider adverse effects such as falls and fractures. Walking can be recommended when older adults have the strength, balance, and cognition to perform it safely and within their limitations, otherwise the risks of falling may increase (Jefferis et al., 2015). For older adults without sufficient capacity for walking programs, a staged approach is recommended to regain sufficient strength and balance before walking unsupervised; otherwise, a paradoxical increase in risk of fractures may be observed in osteoporotic populations advised to walk as their only intervention for bone health.

Currently the most robust evidence for the oldest-old and frail adult supports targeted specific exercise recommendations addressing pervasive deficits of sarcopenia and mobility impairment and elevated risk of injurious falls with resistance training and balance training, respectively (Chodzko-Zajko et al., 2009). In addition, aerobic activities such as walking are important to add where appropriate and safe, to optimize the functional and NCD-related benefits.

Unfortunately, existing community programs for the frail elderly adults often fall short of such evidence-based standards (Burton, Lewin, & Boldy, 2015). In addition, the plethora of benefits of isolated resistance training are often unrecognized as a rationale for this modality of exercise. Given that improvements in muscle strength and balance are achievable with evidence-based, progressive, and robust resistance and balance training strategies (Chodzko-Zajko et al., 2009), this staged approach to improvement in functional and health status in the oldest-old is critical to desired outcomes.

Conclusions

This review highlights the importance, and complexity, of promoting PA among older adults. In considering global health, PA promotion needs to extend beyond policies focusing on NCD prevention alone, to areas of preserving functional capacity, neuromotor abilities, balance co-ordination, reaction time, and neurological or cognitive health.

PA is a major contributor to successful "healthy aging," encompassing clinical, psychological, and social benefits. Population-level strategies need to consider creating awareness among policymakers of the importance of PA in healthy aging, as this occurs currently in few low-to-middle–income countries. Policy and community priorities should focus on raising awareness of relationships between PA and health in older adults, as well as providing better facilities and PA programs in the community which cater to individual limitations, preferences, and evidence-based needs of older adults. (Franco et al., 2015). This may require social marketing and health communication strategies, to reframe the discourse on PA for older adults "beyond NCD prevention alone". Research recommendations should focus on better understanding of the health outcomes from strength and balance training, which are less commonly assessed than aerobic activities. Further, dose–response relationships require further elucidation (Hughes et al., 2011).

PAGs distil the evidence into clinically usable recommendations, and should then be regularly monitored through population surveillance systems. Consistent national surveillance of PA over the long-term is not common and is influenced by changes to questions and measures used. Key recommended components of strength and balance are rarely monitored at the population level and are seldom included in public health strategies to promote PA to older adults. New public health approaches are required that reappraise and include these evidence-based components, both in surveillance systems and in the delivery of programs to target inactivity among older adults.

Community programs for community-dwelling adults should consider center- and home-based programs in combination rather than isolation. Center-based programs have achieved good adherence in the short term and greater effects on PA behavior change. To maintain their effects, gradual transition to less-intensive programs along with some type of remote supervision is recommended to avoid relapse. Better methods are needed to set behavioral goals, increase self-monitoring, and provide feedback using new technologies in real time in the home or community setting.

In the oldest-old and frail adults, the rationale for PA recommendations includes both minimization of age-related changes in physiology which contribute to the risk of NCDs and disability as well as adjunctive (coronary heart disease, type 2 diabetes, obesity, pulmonary disease, neurological disease, chronic renal failure, etc.) or alternative (depression and cognitive impairment) treatment of established chronic diseases and disability. The older and frailer the individual, the greater the rationale for the addition of progressive resistance and balance training to aerobic exercise programs, given the prevalence of sarcopenia, mobility impairment, and functional dependency in this group. Frailty is not a contraindication to exercise, but conversely, one of the most important reasons to prescribe it.

Supplementary Material

Please visit the article online at http://gerontologist.oxfordjournals.org/ to view supplementary material.

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References

Ahlskog, J. E., Geda, Y. E., Graff-Radford, N. R., & Petersen, R. C. (2011). Physical exercise as a preventive or disease-modifying treatment of dementia and brain aging. *Mayo Clinic Proceedings*, **86**, 876–884. doi:10.4065/mcp.2011.0252

Angevaren, M., Aufdemkampe, G., Verhaar, H., Aleman, A., & Vanhees, L. (2008). Physical activity and enhanced fitness to improve cognitive function in older people without known cognitive impairment. *Cochrane Database of Systematic Reviews*, **16**, CD005381. doi:10.1002/14651858.CD005381.pub3

Ashworth, N. L., Chad, K. E., Harrison, E. L., Reeder, B. A., & Marshall, S. C. (2005). Home versus center based physical activity programs in older adults. *Cochrane Database of Systematic Reviews*, **25**, CD004017. doi:10.1002/14651858.CD004017

Baert, V., Gorus, E., Mets, T., Geerts, C., & Bautmans, I. (2011). Motivators and barriers for physical activity in the oldest old: A systematic review. *Ageing Research Reviews*, **10**, 464–474. doi:10.1016/j.arr.2011.04.001

Batty, G. D. (2002). Physical activity and coronary heart disease in older adults. *The European Journal of Public Health*, **12**, 171–176.

Bherer, L. (2015). Cognitive plasticity in older adults: Effects of cognitive training and physical exercise. *Annals of the New York Academy of Sciences*, **1337**, 1–6.

Blankevoort, C. G., Van Heuvelen, M. J., Boersma, F., Luning, H., de Jong, J., & Scherder, E. I. (2010). Review of effects of physical activity on strength, balance, mobility and ADL performance in elderly subjects with dementia. *Dementia and Geriatric Cognitive Disorders*, **30**, 392–402. doi:10.1159/000321357

Blondell, S. J., Hammersley-Mather, R., & Veerman, J. L. (2014). Does physical activity prevent cognitive decline and dementia? A systematic review and meta-analysis of longitudinal studies. *BMC Public Health*, **14**, 510. doi:10.1186/1471-2458-14-510

Boyle, P. A., Buchman, A. S., Wilson, R. S., Leurgans, S. E., & Bennett, D. A. (2009). Association of muscle strength with the risk of Alzheimer disease and the rate of cognitive decline in community-dwelling older persons. *Archives of Neurology*, **66**, 1339–1344. doi:10.1001/archneurol.2009.240

Bridle, C., Spanjers, K., Patel, S., Atherton, N. M., & Lamb, S. E. (2012). Effect of exercise on depression severity in older people: Systematic review and meta-analysis of randomised controlled trials. *The British Journal of Psychiatry*. **201**, 180–185. doi:10.1192/bjp.bp.111.095174

Burns, J. M., Johnson, D. K., Watts, A., Swerdlow, R. H., & Brooks, W. M. (2010). Reduced lean mass in early Alzheimer disease and its association with brain atrophy. *Archives of Neurology*, **67**, 428–433. doi:10.1001/archneurol.2010.38

Burton, E., Lewin, G., & Boldy, D. (2015). A systematic review of physical activity programs for older people receiving home care services. *Journal of Aging and Physical Activity*, **23**, 460–470. doi:10.1123/japa.2014-0086

Cadore, E. L., Rodriguez-Manas, L., Sinclair, A., & Izquierdo, M. (2013). Effects of different exercise interventions on risk of falls, gait ability, and balance in physically frail older adults: A systematic review. *Rejuvenation Research*, **16**, 105–114. doi:10.1089/rej.2012.1397

Cameron, I. D., Gillespie, L. D., Robertson, M. C., Murray, G. R., Hill, K. D., Cumming, R. G., & Kerse, N. (2012). Interventions for preventing falls in older people in care facilities and hospitals. *Cochrane Database of Systematic Reviews*, **12**, CD005465. doi:10.1002/14651858.CD005465.pub3

Canadian Society for Exercise Physiology. (2012). Canadian Physical Activity Guidelines. Ottawa, Canada: Canadian Society for Exercise Physiology. Retrieved from http://www.csep.ca/CMFiles/Guidelines/CSEP_Guidelines_Handbook.pdf

Centers for Disease Control and Prevention. (2006). Trends in strength training—United States, 1998–2004. *MMWR Morbidity Mortality Weekly Report*, **55**, 769–772.

Centers for Disease Control and Prevention. (2013). Adult participation in aerobic and muscle-strengthening physical activities—United States in 2011. *MMWR Morbidity Mortality Weekly Report*, **62**, 326–330.

Cesari, M., Vellas, B., Hsu, F. C., Newman, A. B., Doss, H., King, A. C., … Pahor, M.; for the LIFE Study Group. (2015). A physical activity intervention to treat the frailty syndrome in older persons—Results from the LIFE-P study. *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences*, **70**, 216–222.

Chase, J.-A. D. (2013). Physical activity interventions among older adults: A literature review. *Research and Theory for Nursing Practice*, **27**, 53–80. doi:10.1891/1541-6577.27.1.53

Chase, J.-A. D. (2015). Interventions to increase physical activity among older adults: A meta-analysis. *The Gerontologist*, **55**, 706–718. doi:10.1093/geront/gnu090

Chen, H., Zhang, S. M., Schwarzschild, M. A., Heman, M. A., & Ascherio, A. (2005). Physical activity and the risk of Parkinson disease. *Neurology*, **64**, 664–669. doi:10.1212/01.WNL.0000151960.28687.93

Chin, A. P. M. J., van Uffelen, J. G., Riphagen, I., & van Mechelen, W. (2008). The functional effects of physical exercise training in frail older people: A systematic review. *Sports Medicine*, **38**, 781–793.

Chodzko-Zajko, W. J., Proctor, D. N., Fiatarone Singh, M. A., Minson, C. T., Nigg, C. R., Salem, G. J., & Skinner, J. S.; American College of Sports Medicine. (2009). Exercise and physical activity in older adults. *Medicine and Science in Sports and Exercise*, **41**, 1510–1530. doi:10.1249/MSS.0b013e3181a0c95c

Chou, C. H., Hwang, C. L., & Wu, Y. T. (2012). Effect of exercise on physical function, daily living activities, and quality of life in the frail older adults: A meta-analysis. *Archives of Physical Medicine and Rehabilitation*, **93**, 237–244. doi:10.1016/j.apmr.2011.08.042

Chung, C. L., Thilarajah S., & Tan D. (2016) Effectiveness of resistance training on muscle strength and physical function in people with Parkinson's disease: A systematic review and meta-analysis. *Clinical Rehabilitation*, **30**, 11–23. doi:10.1177/0269215515570381

Conn, V. S., Valentine, J. C., & Cooper, H. M. (2002). Interventions to increase physical activity among aging adults: A meta-analysis. *Annals of Behavioral Medicine*, **24**, 120–200. doi:10.1207/S15324796ABM2403_04

Conn, V. S., Minor, M. A., Burks, K. J., Rantz, M. J., & Pomeroy, S. H. (2003). Integrative review of physical activity intervention research with aging adults. *Journal of the American Geriatrics Society*, **51**, 1159–1168. doi:10.1046/j.1532-5415.2003.51365.x

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., … Oja, P. (2003). International physical activity questionnaire: 12-Country reliability and validity. *Medicine and Science in Sports and Exercise*, **35**, 1381–1395. doi:10.1249/01.MSS.0000078924.61453.FB

Crimmins, E. M., 2015. Lifespan and healthspan: Past, present, and promise. *The Gerontologist*, **55**, 901–911. doi:10.1093/geront/gnv130

Cruz-Jentoft, A. J., Landi, F., Schneider, S. M., Zuniga, C., Arai, H., Boirie, Y., … Cederholm, T. (2014). Prevalence of and interventions for sarcopenia in ageing adults: A systematic review. Report of the International Sarcopenia Initiative EWGSOP and IWGS). *Age and Ageing*, **43**, 748–759. doi:10.1093/ageing/afu115

de Labra, C., Guimaraes-Pinheiro, C., Maseda, A., Lorenzo, T., & Millan-Calenti, J. C. (2015). Effects of physical exercise interventions in frail older adults: A systematic review of randomized controlled trials. *BMC Geriatrics*, **15**, 154.

De Rezende, L. F., Rey-López, J. P., Matsudo, V. K., & do Carmo Luiz, O. (2014). Sedentary behavior and health outcomes among older adults: A systematic review. *BMC Public Health*, **14**, 333. doi:10.1186/1471-2458-14-333

Diep, L., Kwagyan, J., Kurantsin-Mills, J., Weir, R., & Jayam-Trouth, A. (2010). Association of physical activity level and stroke outcomes in men and women: A meta-analysis. *Journal of Women's Health*, **19**, 1815–1822. doi:10.1089/jwh.2009.1708

Ecclestone, N. A., Myers, A. M., & Paterson, D. H. (1998). Tracking older participants of twelve physical activity classes over a three-year period. *Journal of Aging and Physical Activity*, **6**, 70–82.

El-Khoury, F., Cassou, B., Charles, M. A., & Dargent-Molina P. (2013). The effect of fall prevention exercise programmes on fall induced injuries in community dwelling older adults: Systematic review and meta-analysis of randomised controlled trials. British Medical Journal, 347, f6234. doi:10.1136/bmj.f6234

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., … Kramer, A. F. (2011). Exercise training increases size of hippocampus and improves memory. *Proceedings of the National Academy of Sciences USA*, **108**, 3017–3022. doi:10.1073/pnas.1015950108

Fiatarone Singh, M. A. (2014). Exercise, nutrition and managing hip fracture in older persons. *Current Opinion in Clinical Nutrition & Metabolic Care*, **17**, 12–24. doi:10.1097/MCO.0000000000000015

Fiatarone Singh, M. A., O'Neill, E. F., Ryan, N. D., Clements, K. M., Solares, G. R., Nelson, M. E., … Evans, W. J. (1994). Exercise training and nutritional supplementation for physical frailty in very elderly people. *The New England Journal of Medicine*, **330**, 1769–1775.

Franco, M. R., Tong, A., Howard, K., Sherrington, C., Ferreira, P. H., Pinto, R. Z., & Ferreira, M. L. (2015). Older people's perspectives on participation in physical activity: A systematic review and thematic synthesis of qualitative literature. *British Journal of Sports Medicine*. doi:10.1136/bjsports-2014-094015

Fried, L. P., Tangen, C. M., & Walston, J. (2001). Frailty in older adults: Evidence for a phenotype. *The Journals of Gerontology: Biological and Medical Sciences*, **56**, M146–M156. doi:10.1093/gerona/56.3.M146

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., … Swain, D. P.; American College of Sports Medicine. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Medicine and Science in Sports and Exercise*, 1334–1359. doi:10.1249/MSS.0b013e318213fefb

Gates, N., Fiatarone Singh, M. A., Sachdev, P. S., & Valenzuela, M. (2013). The effect of exercise training on cognitive function in older adults with mild cognitive impairment: A meta-analysis of randomized controlled trials. *The American Journal of Geriatric Psychiatry*, **21**, 1086–1097. doi:10.1016/j.jagp.2013.02.018

Gillespie, L. D., Robertson, M. C., Gillespie, W. J., Sherrington, C., Gates, S., Clemson, L. M., & Lamb, S. E. (2012). Interventions for preventing falls in older people living in the community. *The Cochrane Database of Systematic Reviews*, **9**, CD007146. doi:10.1002/14651858.CD007146.pub3

Gine-Garriga, M., Roque-Figuls, M., Coll-Planas, L., Sitja-Rabert, M., & Salva, A. (2014). Physical exercise interventions for improving performance-based measures of physical function in community-dwelling, frail older adults: A systematic review and meta-analysis. *Archives of Physical Medicine and Rehabilitation*, **95**, 753–769. doi:10.1016/j.apmr.2013.11.007

Goldstein, L. B., Adams, R., Alberts, M. J., Appel, I. J., Brass, L. M., Bushnell, C. D., … Sacco, R. L. (2006). Primary prevention of ischemic stroke: A guideline from the American Heart Association and American Stroke Association. *Circulation*, **1132**, e873–e923.

Gordon, B. A., Benson, A. C., Bird, S. R., & Fraser, S. F. (2009). Resistance training improves metabolic health in type 2 diabetes: A systematic review. *Diabetes Research and Clinical Practice*, **83**, 157–175. doi:10.1016/j.diabres.2008.11.024

Granacher, U., Muehlbauer, T., Zahner, L., Gollhofer, A., & Kressig, R. W. (2011). Comparison of traditional and recent approaches in the promotion of balance and strength in older adults. *Sports Medicine*, **41**, 377–400. doi:10.2165/11539920-000000000-00000

Grøntved, A., Rimm, E. B., Willett, W. C., Andersen, L. B., & Hu, F. B. (2012). A prospective study of weight training and risk of type 2 diabetes in men. *Archives of Internal Medicine*, **172**, 1306–1312. doi:10.1371/journal.pmed.1001587

Grøntved, A., Pan, A., Mekary, R. A., Stampfer, M., Willett, W. C., Manson, J. E., & Hu, F. B. (2014). Muscle-strengthening and conditioning activities and risk of type 2 Diabetes: A prospective study in two cohorts of US women. *PLoS One*, **11**, 1. doi:10.1371/journal.pmed.1001587

Harvey, J. A., Chastin, S. F. M., & Skelton, D. A. (2015). How sedentary are older people? A systematic review of the amount of sedentary behavior. *Journal of Aging and Physical Activity*, **23**, 471–487. doi:10.1123/japa.2014-0164

Heyn, P. C., Johnson, K. E., & Kramer, A. F. (2008). Endurance and strength training outcomes on cognitively impaired and cognitively intact older adults: A meta-analysis. *The Journal of Nutrition, Health & Aging*, **12**, 401–409. doi:10.1007/BF02982674

Howe, T. E., Rochester, L., Neil, F., Skelton, D. A., & Ballinger, C. (2011). Exercise for improving balance in older people. *Cochrane Database of Systematic Reviews*, **11**, CD004963. doi:10.1002/14651858.CD004963.pub3

Hughes, S. L., Leith, K. H., Marquez, D. X., Moni, G., Nguyen, H. Q., Desai, P., & Jones, D. L. (2011). Physical activity and older adults: Expert consensus for a new research agenda. *The Gerontologist*, **51**, 822–832. doi:10.1093/geront/gnr106

Hupin, D., Roche, F., Gremeaux, V., Chatard, J. C., Oriol, M., Gaspoz, J. M., … Edouard, P. (2015). Even a low-dose of moderate-to-vigorous physical activity reduces mortality by 22% in adults aged >= 60 years: A systematic review and meta-analysis. *British Journal of Sports Medicine*, **49**, 1262–1267. doi:10.1136/bjsports-2014-094306

Jefferis, B. J., Merom, D., Sartini, C., Wannamethee, S. G., Ash, S., Lennon, L. T., … Whincup, P. H. (2015). Physical activity and falls in older men: The critical role of mobility limitations. *Medicine and Science in Sports and Exercise*, **47**, 2119–2118. doi:10.1249/MSS.0000000000000635

Kalache, A., Aboderin, I., & Hoskins, I. (2002). Compression of morbidity and active ageing: Key priorities for public health policy in the 21st century. *Bulletin of the World Health Organization*, **80**, 243–244.

Kaliman, P., Párrizas, M., Lalanaza, J. F., Camins, A., Escorihuela, R. M., & Pallas, M. (2011). Neurophysiological and epigenetic effects of physical exercise on the aging process. *Ageing Research Reviews*, **10**, 475–486. doi:10.1016/j.arr.2011.05.002

Kay, S. J., & Fiatarone Singh, M. A. (2006). The influence of physical activity on abdominal fat: A systematic review of the literature. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, **7**, 183–200. doi:10.1111/j.1467-789X.2006.00250.x

Kemmler, W., Haberle, L., & von Stengel, S. (2013). Effects of exercise on fracture reduction in older adults: A systematic review and meta-analysis. *Osteoporosis International*, **24**, 1937–1950. doi:10.1007/s00198-012-2248-7

King, A. C., Rejeski, W. J., & Buchner, D. M. (1998). Physical activity interventions targeting older adults: A critical review and recommendations. *American Journal of Preventive Medicine*, **15**, 316–333.

Klavestrand, J., & Vingård, E. (2009). The relationship between physical activity and health-related quality of life: A systematic review of current evidence. *Scandinavian Journal of Medicine and Science in Sports*, **19**, 300–312. doi:10.1111/j.1600-0838.2010.01113.x

Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., & Katzmarzyk, P. T.; Lancet Physical Activity Series Working Group. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *The Lancet*, **380**, 219–229. doi:10.1016/S0140-6736(12)61031-9

Lima, L. O., Scianni, A., & Rodrigues-de-Paula, F. (2013). Progressive resistance exercise improves strength and physical performance in people with mild to moderate Parkinson's disease: A systematic review. *Journal of Physiotherapy*, **59**, 7–13. doi:10.1016/S1836-9553(13)70141-3

Liu, C. J., & Latham, N. K. (2009). Progressive resistance strength training for improving physical function in older adults. *Cochrane Database of Systematic Reviews*, **3**, CD002759. doi:10.1002/14651858.CD002759.pub2

Liu, C. K., & Fielding, R. A. (2011). Exercise as an intervention for frailty. *Clinics in Geriatric Medicine*, **27**, 101–110. doi:10.1016/j.cger.2010.08.001

Liu, C. J., & Latham, N. (2011). Can progressive resistance strength training reduce physical disability in older adults?

A meta-analysis study. *Disability and Rehabilitation*, **33**, 87–97. doi:10.1002/14651858.CD002759.pub2

Ludlow, A. T., Zimmerman, J. B., Witkowski, S., Hearn, J. W., Hatfield, B. D., & Roth, S. M. (2008). Relationship between physical activity level, telomere length, and telomerase activity. *Medicine and Science in Sports and Exercise*, **40**, 1764–1771. doi:10.1249/MSS.0b013e31817c92aa

McAuley, E., Blissmer, B., Marquez, D. X., Jerome, G. J., Kramer, A. F., & Katula, J. (2000). Social relations, physical activity, and well-being in older adults. *Preventive Medicine*, **31**, 608–617. doi:10.1006/pmed.2000.0740

McClure, R. J., Turner, C., Peel, N., Spinks, A., Eakin, E., & Hughes, K. (2005). Population-based interventions for the prevention of fall-related injuries in older people. *Cochrane Database of Systematic Reviews*, **1**, CD004441. doi:10.1002/14651858.CD004441.pub2

McGinley, S. K., Armstrong, M. J., Boule, N. G., & Sigal, R. J. (2015). Effects of exercise training using resistance bands on glycaemic control and strength in type 2 diabetes mellitus: A meta-analysis of randomised controlled trials. *Acta Diabetologica*, **52**, 221–230. doi:10.1007/s00592-014-0594-y

McNeill, L. H., Kreuter, M. W., & Subramanian, S. V. (2006). Social environment and physical activity: A review of concepts and evidence. *Social Science & Medicine*, **63**, 1011–1022. doi:10.1016/j.socscimed.2006.03.012

Merom, D., Pye, V., Macniven, R., van der Ploeg, H., Milat, A., Sherrington, C., & Bauman, A. (2012). Prevalence and correlates of participation in fall prevention exercise/physical activity by older adults. *Preventive Medicine*, **55**, 613–617. doi:10.1016/j.ypmed.2012.10.001

Motl, R. W., & McAuley, E. (2010). Physical activity, disability, and quality of life in older adults. *Physical Medicine and Rehabilitation Clinics of North America*, **21**, 299–308. doi:10.1016/j.pmr.2009.12.006

National Institute on Aging, National Institutes of Health, and World Health Organisation. (2011). Global health and aging. NIH Publication, 11-7737 (October 2011). Retrieved November 2015, from http://www.who.int/ageing/publications/global_health.pdf

Neidrick, T. J., Fick, D. M., & Loeb, S. J. (2012). Physical activity promotion in primary care targeting the older adult. *Journal of the American Academy of Nurse Practitioners*, **24**, 405–416. doi:10.1111/j.1745-7599.2012.00703.x

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., Macera, C. A., & Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise*, **39**, 1435–1445. doi:10.1249/mss.0b013e3180616aa2

Netz, Y., Wu, M. J., Becker, B. J., & Tenebaum, G. (2005). Physical activity and psychological well-being in advanced age: A meta-analysis of intervention studies. *Psychology and Aging*, **20**, 272–284.

Norton, S., Matthews, F. E., Barnes, D. E., Yaffe, K., & Brayne, C. (2014). Potential for primary prevention of Alzheimer's disease: An analysis of population-based data. *The Lancet Neurology*, **13**, 788–794. doi:10.1016/S1474-4422(14)70136-X

Orr, R., Raymond, J., & Fiatarone Singh, M. (2008). Efficacy of progressive resistance training on balance performance in older adults: A systematic review of randomized controlled trials. *Sports Medicine*, **38**, 317–343. doi:10.2165/00007256-200838040-00004

Pahor, M., Guralnik, J. M., Ambrosius, W. T., Blair, S., Bonds, D. E., … Williamson, J.D.; LIFE Study Investigators. (2014). Effect of structured physical activity on prevention of major mobility disability in older adults: The LIFE study randomized clinical trial. *The Journal of the American Medical Association*, **311**, 2387–2396. doi:10.1001/jama.2014.5616

Paterson, D. H., & Warburton, D. E. R. (2010). Physical activity and functional limitations in older adults: A systematic review related to Canada's Physical Activity Guidelines. *International Journal of Behavioral Nutrition and Physical Activity*, **7**, 1–22. doi:10.1186/1479-5868-7-38

Pedišić, Ž., & Bauman, A. (2015). Accelerometer-based measures in physical activity surveillance: Current practices and issues. *British Journal of Sports Medicine*, **49**, 219–223. doi:10.1136/bjsports-2013-093407

Peterson, M. D., Sen, A., & Gordon, P. M. (2011). Influence of resistance exercise on lean body mass in aging adults: A meta-analysis. *Medicine and Science in Sports and Exercise*, **43**, 249–258. doi:10.1249/MSS.0b013e3181eb6265

Petrescu-Prahova, M., Belza, B., Kohn, M., & Miyawaki, C. (2015). Implementation and maintenance of a community-based older adult physical activity program. *The Gerontologist*. Advance online publication. doi:10.1093/geront/gnv024

Public Health Agency of Canada. (2011). Physical activity tips for older adults 65 years and older). Cat: HP10-16/4-2011E-PDF; ISBN: 978-1-100-18925-3. Retreived January 2015, from http://www.phac-aspc.gc.ca/hp-ps/hl-mvs/pa-ap/08paap-eng.php

Raymond, M. J., Bramley-Tzerefos, R. E., Jeffs, K. J., Winter, A., & Holland, A. E. (2013). Systematic review of high-intensity progressive resistance strength training of the lower limb compared with other intensities of strength training in older adults. *Archives of Physical Medicine and Rehabilitation*, **94**, 1458–1472. doi:10.1016/j.apmr.2013.02.022

Sagar, V. A., Davies, E. J., Briscoe, S., Coats, A. J. S, Dalal, H. M., Lough, F., … Taylor, R. S. (2015). Exercise-based rehabilitation for heart failure: Systematic review and meta-analysis. *Open Heart*, **2**, e000163. doi:10.1136/openhrt-2014-000163

Scherder, E., Scherder, R., Verburgh, L., Konigs, M., Blom, M., Kramer, A. F., & Eggemont, L. (2014). Executive functions of sedentary elderly may benefit from walking: A systematic review and meta-analysis. *The American Journal of Geriatric Psychiatry*, **22**, 782–791. doi:10.1016/j.jagp.2012.12.026

Schoenfeld, B. J., Wilson, J. M., Lowery, R. P., & Krieger, J. W. (2014). Muscular adaptations in low- versus high-load resistance training: A meta-analysis. *European Journal of Sport Science*, **16**, 1–10. doi:1080/17461391.2014.989922

Sherrington, C., Tiedemann, A., Fairhall, N., Close, J. C., & Lord, S. R. (2011). Exercise to prevent falls in older adults: An updated meta-analysis and best practice recommendations. *New South Wales Public Health Bulletin*, **22**, 78–83. doi:10.1071/NB10056

Shu, H. F., Yang, T., Yu, S. X., Huang, H. D., Jiang, L. L., Gu, J. W., & Kuang, Y. Q. (2014). Aerobic exercise for Parkinson's disease: A systematic review and meta-analysis of randomized controlled trials. *PLoS One*, **9**, e100503. doi:10.1371/journal.pone.0100503

Silveira, H., Moraes, H., Oliveira, N., Coutinho, E. S., Laks, J., & Deslandes, A. (2013). Physical exercise and clinically depressed patients: A systematic review and meta-analysis. *Neuropsychobiology*, **67**, 61–68. doi:10.1159/000345160

Singh, N. A., Quine, S., Clemson, L. M., Williams, E. J., Williamson, D. A., Stavrinos, T. M., … Singh, M. A. (2012). Effects of high-intensity progressive resistance training and targeted multidisciplinary treatment of frailty on mortality and nursing home admissions after hip fracture: A randomized controlled trial. *Journal of the American Medical Directors Association*, **13**, 24–30. doi:10.1016/j.jamda.2011.08.005

Sjögren, P., Fisher, R., Kallings, L., Svenson, U., Roos, G., & Hellenius, M. L. (2014). Stand up for health-avoiding sedentary behaviour might lengthen your telomeres: Secondary outcomes from a physical activity RCT in older people. *British Journal of Sports Medicine*, **48**, 1407–1409. doi:10.1136/bjsports-2013-093342

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G. F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: A meta-analysis of prospective studies. *Journal of Internal Medicine*, **269**, 107–117. doi:10.1111/j.1365-2796.2010.02281.x

Steib, S., Schoene, D., & Pfeifer, K. (2010). Dose-response relationship of resistance training in older adults: A meta-analysis. *Medicine and Science in Sports and Exercise*, **42**, 902–914. doi:10.1249/MSS.0b013e3181c34465

Tak, E., Kuiper, R. T., Chorus, A., & Hopman-Rock, M. (2013). Prevention of onset and progression of basic ADL disability by physical activity in community dwelling older adults: A meta-analysis. *Ageing Research Reviews*, **12**, 329–338. doi:10.1016/j.arr.2012.10.001

Thacker, E. L., Chen, H., Patel, A. V., McCullough, M. L., Calle, E. E., Thun, M. J., Schwarzschild, M. A., & Ascherio, A. (2008). Recreational physical activity and risk of Parkinson's disease. *Movement Disorders*, **23**, 69–74. doi:10.1002/mds.21772

Theou, O., Stathokostas, L., Roland, K. P., Jakobi, J. M., Patterson, C., Vandervoort, A. A., & Jones, G. R. (2011). The effectiveness of exercise interventions for the management of frailty: A systematic review. *Journal of Aging Research*, **2011**, 569194. doi:10.4061/2011/569194

Thiebaud, R. S., Funk, M. D., & Abe, T. (2014). Home-based resistance training for older adults: A systematic review. *Geriatrics & Gerontology International*, **14**, 750–757. doi:10.1111/ggi.12326

Thomas, S., Mackintosh, S., & Halbert, J. (2010). Does the 'Otago exercise programme' reduce mortality and falls in older adults? A systematic review and meta-analysis. *Age and Ageing*, **39**, 681–687. doi:10.1093/ageing/afq102

United Nations Department of Economic and Social Affairs, Population Division. (2013). World Population Ageing (Report ST/ESA/SER.A/348). Retrieved from http://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeingReport2013.pdf

U. S. Health and Human Services. (2008). *Physical Activity Guidelines Advisory Committee Report*. Washington, DC: U.S. Department of Health and Human Services.

Valenzuela, T. (2012). Efficacy of progressive resistance training interventions in older adults in nursing homes: A systematic review. *Journal of the American Medical Directors Association*, **13**, 418–428. doi:10.1016/j.jamda.2011.11.001

van der Bij, A. K., Laurant, M. G., & Wensing, M. (2002). Effectiveness of physical activity interventions for older adults: A review. *American Journal of Preventive Medicine*, **22**, 120–133. doi:10.1016/S0749-3797(01)00413-5

Voelcker-Rehage, C., Godde, B., & Staudinger, U. M. (2011). Cardiovascular and coordination training differentially improve cognitive performance and neural processing in older adults. *Frontiers in Human Neuroscience*, **5**, 26. doi:10.3389/fnhum.2011.00026

Vogel, T., Brechat, P. H., Lepretre, P. M., Kaltenbach, G., Berthel, M., & Lonsdorfer, J. (2009). Health benefits of physical activity in older patients: A review. *International Journal of Clinical Practice*, **63**, 303–320.

Voukelatos, A., Merom, D., Sherrington, C., Rissel, C., Cumming, R. G., & Lord, S. R. (2015). The impact of a home-based walking programme on falls in older people: The Easy Steps randomised controlled trial. *Age and Aging*, **44**, 377–388. doi:10.1093/ageing/afu186

Wannamethee, S. G., & Shaper, A. G. (2014). Physical activity and the prevention of stroke. *European Journal of Preventive Cardiology*, **6**, 213–216. doi:10.1177/204748739900600404

Warburton, D. E., Charlesworth, S., Ivey, A., Nettlefold, L., & Bredin, S. S. (2010). A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. *The International Journal of Behavioral Nutrition and Physical Activity*, **7**, 39. doi:10.1186/1479-5868-7-39

Wendel-Vos, G. C. W., Schuit, A. J., Feskens, E. J. M., Boshuizen, H. C., Verschuren, W. M. M., Saris, W. H. M., & Kromhout, D. (2004). Physical activity and stroke. A meta-analysis of observational data. *International Journal of Epidemiology*, **33**, 787–798. doi:10.1093/ije/dyh168

Windle, G. (2014). Exercise, physical activity and mental well-being in later life. *Reviews in Clinical Gerontology*, **24**, 319–325. doi:10.1017/S0959259814000173

Windle, G., Hughes, D., Linck, P., Russell, I., & Woods, B. (2010). Is exercise effective in promoting mental well-being in older age? A systematic review. *Aging & Mental Health*, **14**, 652–669. doi:10.1080/13607861003713232

World Health Organization. (2002). *Active ageing: A policy framework*. (WHO/NMH/NPH/02.8), Geneva: WHO Noncommunicable Diseases and Mental Health Cluster. Retrieved May 2015, from http://whqlibdoc.who.int/hq/2002/who_nmh_nph_02.8.pdf

World Health Organization. (2010a). Physical activity and older adults: Recommended levels of physical activity for adults aged 65 and above. Retrieved from http://www.who.int/dietphysicalactivity/factsheet_recommendations/en/

World Health Organization. (2010b). WHO Study on global AGEing and adult health (SAGE 2007–2010). Retrieved from http://www.who.int/healthinfo/systems/sage/en

World Health Organization. (2015). *World report on ageing and health*. Geneva: WHO. ISBN: 978 92 4 156504 2

World Health Survey. (2002). Retrieved January 2015, from http://apps.who.int/healthinfo/systems/surveydata/index.php/catalog/whs/about Geneva: WHO.

Xue, Q. L. (2011). The frailty syndrome: Definition and natural history. *Clinics in Geriatric Medicine*, **27**, 1–15. doi:10.1016/j.cger.2010.08.009

Yang, Z., Scott, C. A., Mao, C., Tang, J., & Farmer, A. J. (2014). Resistance exercise versus aerobic exercise for type 2 diabetes: A systematic review and meta-analysis. *Sports Medicine*, **44**, 487–99. doi:10.1007/s40279-013-0128-8