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Exercise in Octogenarians: How Much Is Too Little?

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Abstract

The global population is rapidly aging, with predictions of many more people living beyond 85 years. Age-related physiological adaptations predispose to decrements in physical function and functional capacity, the rate of which can be accelerated by chronic disease and prolonged physical inactivity. Decrements in physical function exacerbate the risk of chronic disease, disability, dependency, and frailty with advancing age. Regular exercise positively influences health status, physical function, and disease risk in adults of all ages. Herein, we review the role of structured exercise training in the oldest old on cardiorespiratory fitness and muscular strength and power, attributes critical for physical function, mobility, and independent living.

INTRODUCTION

There is a global demographic shift toward an aging population. The number of people aged 65 and older will rapidly grow, with estimates of over 1.5 billion people by 2050 (1). Within this population shift, individuals aged 85 years and older (the "oldest old") are expected to triple in number and represent one of the fastest-growing communities in the population (2, 3). Significant advances in the detection and management of chronic health conditions have resulted in many seniors living longer with complex health issues.

Physical function and exercise capacity deteriorate with advancing age, a deterioration that can be accelerated by disease and lifestyle factors (4–6). In many elderly individuals, this decrement may be substantial enough to render them unable to perform activities of daily living (ADLs) without significant difficulties or assistance (7, 8). A loss of living independence comes with high personal and societal costs. Therefore, it has become essential to develop effective lifestyle strategies to preserve physical function, independent living, and self-efficacy late in life.

Aerobic and resistance exercise programs lasting several weeks to months partially reverse the age-related deterioration of physical function and functional capacity in previously inactive aged adults (9). However, because exercise-based studies in the oldest old subpopulation are rare, exercise recommendations are based on data extrapolated from "younger older" individuals (60–75 years). Moreover, exercise studies in seniors have rarely assessed the specific training stimulus or dose. Therefore, despite advances in our understanding of the beneficial effects of regular physical activity (PA) and exercise on health status and physical function with advancing age, there is little information on the dose that prevents or enhances these outcomes in the oldest old. These data are essential for designing evidence-based exercise strategies to optimize health and physical function in late life (10).

This review critically addresses the question, "How much exercise is too little in octogenarians?" We briefly review three decades of findings concerning the effects of regular exercise training on cardiorespiratory fitness (CRF) and muscular strength and power in elderly adults. These attributes are central to ambulatory physical function, mobility, and independent living in elderly adults and therefore are of great scientific and clinical interest.

DEFINITIONS OF KEY TERMS

Before discussing the research on the impacts of regular PA or exercise on the health status and physical function in the oldest old, it is essential to distinguish between these two domains. Physical activity (PA) refers to any bodily movement that results from muscular contraction and increases energy expenditure above resting levels (11, 12). Exercise, while sharing many common elements with PA, is a subcategory of PA that is structured, planned, and performed to improve health and physical fitness (11–13).

Although there are several definitions of physical fitness, the term refers to a set of attributes that contributes to the ability to perform physical work, such as cardiorespiratory fitness, muscular strength and power, balance, flexibility, agility, and body composition (14). Functional capacity reflects the ability to perform ADLs that require sustained aerobic metabolism and encompasses many aspects of physical fitness (4).

Aerobic or endurance exercise involves repetitive dynamic skeletal muscle contractions in a large muscle mass over a prolonged period. Resistance or strength exercise causes muscles to repetitively work or hold against an applied force or weight (15, 16). Although there is a plethora of evidence showing that aerobic and resistance exercise results in a broad array of health benefits, the biological and physiological adaptations can differ significantly between these two exercise modes (15). Flexibility exercise enhances the ability to move a joint through its full range of motion, while balance exercise increases the maintenance of the body's equilibrium while stationary or moving (16). Muscular strength refers to the ability of a muscle or muscle group to exert force, while muscular power is the rate at which work can be applied (16). It is important to emphasize that many activities contain both muscular strength and endurance exercise and have adaptations commensurate with both types of training.

The volume or dose of PA or exercise represents the interplay of three factors: frequency (how often), intensity (how hard), and duration (how long). Frequency represents the number of daily, weekly, or monthly exercise sessions, while duration reflects the amount of exercise exposure per session. While frequency and duration are easily defined, the intensity component is more complicated because of several different classification systems. Exercise intensity indices can be in absolute terms, such as the total metabolic cost of the exercise, or relative terms, such as a function of some percentage of measurable maximal capacity (13). Commonly reported objective indices of exercise intensity are the metabolic equivalent of task (MET) and a percentage of maximal oxygen uptake, maximal heart rate, or one-repetition maximal force. Commonly used subjective indices of exercise intensity include the rate of perceived exertion, which involves a somatic rating of effort, and the talk test, which gauges speaking comfort during exercise.

EXERCISE DOSE AND PHYSICAL FUNCTION, HEALTH STATUS, AND CHRONIC DISEASE OUTCOMES

Over the last three decades, a large body of evidence has accumulated that supports a graded PA and exercise dose-response relationship for health and clinical outcomes (13, 17). The mortality benefits obtained are substantial in those engaging in 60–180 min of moderate-to-vigorous-intensity exercise weekly, and additional, although more modest, reduction in risk is observed with increases in exercise dose to a median of 420 min per week (13, 16, 18). Some epidemiological studies have reported a J or U-shaped relationship between mortality and exercise dose, prompting some level of concern that a very large or extreme exercise stimulus may mitigate the noteworthy health and mortality benefits (13, 19, 20). However, recent studies have confirmed that a large exercise volume, generally accomplished for performance goals rather than health benefits, appears neither incrementally better nor worse and still provides superior disease and mortality protection compared to a sedentary lifestyle (13, 19, 20).

The exercise training dose that improves a specific health, clinical, or physiological outcome varies considerably, with some outcomes requiring more activity while others require much less (13, 21). This information needs to be carefully considered within the prescription framework goals to target the desired intervention outcome.

Moreover, there is marked interindividual variability (and potentially sex differences) in the magnitude of adaptations to a given PA or exercise program or exercise dose (21–23). An individual's trainability in physiological outcomes such as maximal oxygen uptake ($\dot{V}O_2$max), resting and exercise heart rate, and arterial blood pressure is determined by the complex interaction of genetic, phenotypic, and environmental factors (22). The HERITAGE study showed that the trainability of $\dot{V}O_2$max has an ∼50% genetic component involving a wide range of genes in healthy humans (24).

There have been numerous discussions in the exercise physiology literature on the dichotomous concept of responders/nonresponders to aerobic and resistance exercise training. Recent findings by Montero & Lundby showed that a nonresponse in $\dot{V}O_2$max was abolished with an additional increase in exercise training dose in healthy young adults (25). Therefore, in addition to hereditary factors, a sufficient exercise dose is an important mediator of the adaptive response in $\dot{V}O_2$max.

Although the public health message should be for all adults to achieve or exceed the current evidence-based PA levels recommended, measurable and clinically relevant benefits in CRF and risk of mortality are obtained with an exercise dose lower than current guidelines. In elderly men, 60 min per week of either walking or cycling was associated with reduced cardiovascular mortality (26), while being an occasional weekly exerciser (one exercise session per week) still conferred a reduction in mortality (27). In a recent investigation of 441 very old adults (average age 87 years), light weekly PA conveyed significant all-cause mortality benefits during a 6-year follow-up (28). These findings are valuable for establishing activity levels that may motivate sedentary individuals to initiate regular PA or exercise training.

BIOLOGICAL AGING AND PHYSICAL FUNCTION: A COMPLEX INDIVIDUAL PROCESS

Aging encompasses a host of cellular-, tissue-, and organ-level changes that can be insidious and deleterious to many domains of physical function and predispose individuals to geriatric syndromes entailing sarcopenia, frailty, and disability. Biological aging does not occur at a uniform rate for everyone, and therefore, individuals at the same chronological age can vary substantially in health and disease status.

Biological aging can be modulated by genetics, environmental factors, dietary habits, and regular PA levels. Self-reported and accelerometry data clearly show that older adults engage in less PA, whether moderate or vigorous, than younger adults during their day (29–31).

Similarities in the biological and physiological adaptations due to physical disuse and sedentary aging have led to the speculation that PA and physical inactivity could heavily influence the rate of systemic aging (14, 32). The pronounced age-related changes in physical function and capacity may be accelerated by prolonged physical inactivity (33). The bedrest model has been useful in investigating the physiological responses to strict physical inactivity. Numerous studies show that even short-term bedrest decreases cardiorespiratory and musculoskeletal function (34–37). A 3-week period of strict bedrest elicits effects on cardiorespiratory function and CRF comparable to 30 years of aging (38).

CHANGES IN CARDIORESPIRATORY FITNESS AND MUSCULAR STRENGTH AND POWER WITH AGING

CRF is a primary metric of functional capacity reflecting the coordinated integration of cardiovascular, respiratory, and neuromuscular organ system function in the distribution and utilization of oxygen by active tissue during physical exertion (6). An extremely high CRF, as indicated by $\dot{V}O_2$max relative to total body mass [>75 mL/(kg$^{-1}\cdot$min^{-1})], is characteristic of high-performing endurance athletes. In contrast, a very low CRF [10–15 mL/(kg$^{-1}\cdot$min^{-1})] may be observed in people with chronic disease or in severely deconditioned aged individuals (39).

Oxygen uptake per kilogram of total body mass is a commonly reported metric of CRF in studies comparing populations of different body sizes and compositions. The practice of using total body mass as the primary scaling factor is relevant for assessing functional capacity, as heavier individuals carry their entire body mass with them during PA (40). However, during vigorous physical exertion, obese individuals may have normal or even superior cardiorespiratory performance because of a large muscle mass and a high metabolic cost of PA (41, 42). Given the sizable changes in body mass and composition in both sexes with aging, careful consideration needs to be given to the scaling practices used to examine exercise and physiological function and cardiorespiratory performance in older adults during acute exercise and with exercise training (43).

Extensive epidemiological and clinical research has shown that laboratory-based measures of CRF during maximal or peak exercise [i.e., $\dot{V}O_2$max, peak oxygen uptake ($\dot{V}O_2$peak), or METs] are powerful predictors of cardiovascular and all-cause mortality irrespective of age, sex, and health status (4–6, 13). Based on these observations, a recent scientific statement from an expert panel emphasized that CRF should be established as a vital health sign of comparable (if not greater) clinical importance and prognostic value for adverse risk as traditional cardiovascular risk factors (5). Of particular importance to this review, CRF is strongly implicated in physical function in the elderly population (5, 44–48).

Cross-sectional examinations show that CRF declines by 4–12% per decade in healthy individuals (49). However, longitudinal studies indicate that the decline in CRF accelerates markedly with each successive decade of adulthood (50, 51), exceeding a 21% per decade reduction in those over the age of 70 years (50). Consequently, $\dot{V}O_2$max (or $\dot{V}O_2$peak) at >70 years is typically only approximately 25–35% of that at middle age (50, 52). It is widely accepted that the capacity for oxygen delivery (circulatory capacity) is primarily responsible for the decline in CRF with aging, although impairments in skeletal muscle oxygen utilization may exert a larger impact with advanced age or chronic disease (53, 54).

The marked reduction in CRF with aging can be further compounded by prolonged physical inactivity, comorbidities, and chronic health conditions (e.g., cardiovascular disease, heart failure, diabetes mellitus, obesity) associated with advancing age (5). Consequently, for many elderly individuals, CRF may reach a value at which ADLs require a significantly higher relative effort to perform, or at which individuals are unable to complete the activity independently (55, 56). Unfortunately, these conditions may result in an individual avoiding physically demanding activities, driving a debilitating cycle of physical inactivity and loss of living functionality.

In community-dwelling adults aged 65–90 years, a $\dot{V}O_2$peak of 18 mL/(kg^{-1}·min^{-1}) (∼5 METs or fivefold resting energy expenditure) distinguished high from low physical function (55). This CRF level might be higher than what is observed in many octogenarians, and therefore they would be less likely to perform daily activities such as vacuuming (∼3.5 METs) and cooking or preparing food (∼2.5 METs) (57, 58).

Sarcopenia is the accelerated loss of skeletal muscle mass with aging or immobility. This disorder can greatly diminish muscle force-generating ability. Skeletal muscle mass declines at a rate of ∼1% per year from middle age, in severe instances reaching a loss of ∼50% by the eighth to the ninth decade of life. While the numbers vary across studies, sarcopenia is reported in 11–50% of those aged 80 and older (59–61). Chronic disease and physical inactivity escalate the decline in muscle mass (62, 63). The complex etiology of sarcopenia involves nutritional intake, protein synthesis, and systemic inflammation.

In concert with changes in skeletal muscle mass, age-related modifications of the neurogenic components of force generation adversely impact overall muscular force generation (64). Reported neurogenic changes with aging include a reduction in motor unit number, an increased excitatory threshold of existing motor units, and increased instability at the neuromuscular junction (64). Decrements in neuromuscular function (e.g., a decline in muscle strength and power) occur more rapidly (3–4% per year) than the loss of muscle mass with aging (65, 66). The decline in muscular strength and power has substantial effects on the performance of ADLs, as inadequate muscular strength makes it difficult to lift and carry objects, while stair climbing is hindered because of reduced lower limb muscular power (67). Accordingly, low levels of muscular strength and power are accurate predictors of physical impairment in older adults (66).

Dynamic balance, underpinned by musculoskeletal and neurological function, declines with aging. Dynamic balance is involved in many ADLs, such as walking and stair climbing, and contributes to the risk of falls. Impairments in balance contribute to the increasing falls risk in the elderly. Therefore, age-associated alterations in dynamic balance are associated with health and independent living consequences.

LIFELONG EXERCISE DELAYS THE MAJOR CONSEQUENCES OF AGING: THE PHYSICAL CAPACITY AND PHYSIOLOGICAL FUNCTION OF THE "FITTEST" SENIORS

Individuals who have engaged in aerobic and resistance exercise for most of their adult lives have a substantially larger physical capacity and enhanced physiological function in many organ systems compared to their untrained or inactive counterparts (68–77). Typical age-related impairments in physical and physiological function are either forestalled or greatly diminished in highly trained seniors. Based on these findings, previous commentaries have suggested that these individuals demonstrate a physiological phenotype of exceptionally successful aging (69).

Arbab-Zadeh et al. found that carefully screened older adults (average age 70 years) who had performed nearly daily vigorous aerobic exercise training and competed regularly in national and regional endurance competitions for at least 25 years were indistinguishable in CRF and cardiac compliance from untrained adults on average 4 decades younger (73). A subsequent series of reports (74–76) from the same laboratory compared committed exercisers (defined as those who participated in 4–5 weekly exercise sessions, at least 30 min per session, for >25 years), casual exercisers (2–3 weekly exercise sessions), and sedentary individuals (no more than 1 weekly exercise session). Committed exercisers were relatively protected against the age-related changes in CRF and cardiac and large vessel (aortic) vascular stiffening, while casual exercisers were not significantly protected compared to sedentary individuals. Collectively, these findings indicate that a weekly exercise dose consistent with current weekly PA guidelines (at least 150 min weekly) diminishes age-related changes in cardiac or large vessel structure and stiffening, and therefore may reduce the risk of developing impairments with senescence.

Recent studies have provided compelling evidence that reinforces the favorable effects of prolonged and vigorous endurance exercise training and competition on the exercise performance of men and women in their late eighth to tenth decades of life (71, 72). CRF in these high-performing octogenarian athletes was over 30% higher than in similarly aged untrained individuals and was more comparable to untrained midlife adults (78, 79). While this higher CRF is likely due to beneficial adaptations in multiple organ systems, muscle biopsies revealed a structural composition that would facilitate greater oxygen utilization, such as a greater capillarization, enzyme content, and mitochondria number (70–72). The cross-sectional nature of these studies does not permit a causative relationship between training history and physiological adaptations to be established. However, it is likely that decades of regular vigorous exercise elicited molecular-, cellular-, and organ-level adaptations that would facilitate a higher level of exercise performance.

Observational studies and meta-analyses have shown that senior athletes with an extensive history of resistance or strength exercise training demonstrate higher muscular maximal strength and power than aged-matched untrained peers (68, 77, 80, 81). Multiple aspects of skeletal muscle structure, including lower and upper limb muscle mass, slow-twitch muscle fiber size, capillarization, and aerobic enzyme content, are all enhanced in endurance- and resistance-trained senior athletes (70–72, 77, 80, 82–85). From a neurogenic perspective, there is evidence that lifelong athletes exhibit a higher number of surviving motor units in a phase of life in which they typically decline (86, 87). Collectively, these findings suggest that lifelong endurance and resistance training preserve several physiological properties of neuromuscular structure and function with advanced age, although the optimal dose of exercise that needs to be performed over a lifetime still needs further clarification.

While these observations are important as they stress the benefits of lifelong aerobic and resistance exercise for cardiovascular, musculoskeletal, and neuromuscular function, many of these lifelong exercisers initiate exercise training early in life, and their typical training stimulus is unrealistic to promote on a population basis. Therefore, more feasible strategies for regular PA and exercise promotion across the entire lifespan are required (74, 75).

CURRENT PHYSICAL ACTIVITY AND EXERCISE RECOMMENDATIONS IN THE ELDERLY

Public health organizations have called for adults of all ages to be more physically active and reduce prolonged sedentary time. Current PA and exercise guidelines for the promotion of health in older adults are not significantly different from evidence-based recommendations for young adults: a threshold of at least 150 min of moderate-intensity aerobic activity or 75 min of vigorous-intensity aerobic activity and 2 days of muscle-strengthening activities per week (15, 88, 89). For older adults, balance and flexibility training, which can be encompassed within activities such as tai chi, Pilates, or strength yoga, is recommended on at least 2 days per week (15, 88, 89). The recommended types and the intensity of PA and exercise are generally very safe in older adults, as exercise-based trials using these guidelines have reported only rare instances of serious adverse events (90).

The American College of Sports Medicine and the American Heart Association have released statements that encourage older adults to exceed the minimum recommendations for PA if there are no medical conditions or physical limitations that would preclude this (88, 91). However, if this is not possible, they should be physically active as much as their abilities and medical conditions allow. Participation above the minimum recommended amounts (>300 min per week) is associated with additional benefits in health and physical function and reduces the risk of inactivity-related chronic diseases (15, 88, 89).

EXERCISE COUNTERS THE MAJOR CONSEQUENCES OF AGING

How much exercise is required to enhance or preserve CRF and skeletal muscle mass, strength, and power in late-life exercisers?

Aerobic Exercise Training

Given its strong relationship to chronic disease and mortality, CRF has received significant research attention in adults of all ages. The importance of CRF to physical function and day-to-day functionality in the elderly is particularly relevant given the previously described aging- and disease-related changes (5, 6). Moreover, improvements in CRF in the least aerobically fit adults are associated with large health benefits and disease risk reduction (92).

A retrospective analysis of 53 studies involving over 2,000 individuals aged 70 years and older found that CRF increased on average by 6–46% with aerobic exercise training programs that were heterogeneous in training duration, frequency, and intensity (93). A recent meta-analysis of 41 trials showed that 30–40 weeks of training 3–4 days weekly at a moderate-to-vigorous intensity (66–73% heart rate reserve) for 40–50 min per session was ideal for increasing CRF in previously sedentary younger older (average age 67 years) adults (94).

In well-screened healthy adults 65 years and older, 12 months of progressive and vigorous aerobic exercise training did not elicit a measurable effect on cardiac and large vessel structure and stiffness despite a sizable increase in CRF (9, 95). In a subsequent study in healthy adults 60 years and older, 12 months of moderate-intensity aerobic exercise combined with a glycation end-product breaker (alagebrium) resulted in approximately 15 years of restoration in cardiac stiffness, while no improvement was seen in the exercise-alone group (96). These findings suggest that older adults may have reduced cardiovascular plasticity, which subsequently limits their capacity to respond to exercise training. A recent 2-year exercise-based study significantly improved CRF and enhanced cardiac compliance in adults aged 45–64 years. These findings indicate a potential sweet spot for exercise interventions to prevent/reverse the substantial age-related changes in cardiovascular structure (79).

Well-controlled studies (e.g., prospective randomized trials) investigating aerobic exercise training in those 80 years and older are much rarer than those in younger older age groups. Further, those available generally involve small samples of subjects with multiple comorbidities and a wide range of physical capacities. Despite the heterogeneity among prior research studies, a similar relative mean improvement (14–15%) in CRF for exercise programs lasting 3–12 months was reported (97–100). The exercise prescription generally involved 2–3 weekly sessions of up to 60 min of moderate-to-vigorous intensity aerobic exercise. Based on these findings, 120–180 min of moderate-to-vigorous aerobic exercise weekly, for several weeks to months, appears to be an exercise dose that results in a sizable increase in CRF, even in adults who initiated exercise training late in life.

Although moderate-intensity aerobic exercise has become the standard exercise prescription for improving CRF in older adults, there has been renewed interest in the health and performance benefits of high-intensity interval training (HIIT) in aged and chronic diseased populations. There is a growing body of literature supporting the effectiveness of HIIT in improving CRF and measures of cardiometabolic health in younger older adults (101–103), but this knowledge does not extend to the oldest old, in whom there are currently no well-controlled, long-term efficacy and safety studies.

While the magnitude may not be as substantial, an exercise dose lower than the PA recommendations may still confer benefits on CRF. A recent randomized controlled trial showed that 75 min of moderate-intensity aerobic exercise weekly for 26 weeks increased CRF by 7% (104). Likewise, a smaller dose of aerobic exercise may still confer mortality benefits, even in the absence of measurable changes in cardiovascular structure (13).

Resistance/Strength Exercise Training

Due to the central role of skeletal muscle in maintaining physical function and mobility, resistance or strength training in frail and nonfrail aged individuals has been an area of intense investigation for over two decades. Resistance exercise has been successful in reversing the typical age-related changes in skeletal muscle mass, power, and strength in older populations. Even frail individuals or those aged over 85 years can achieve measurable improvements in muscular strength and power with several weeks to months of resistance training (105–107).

When resistance or strength exercise is integrated into a multimodal exercise program, favorable effects are also observed in other physical function aspects such as CRF, balance, and gait (108). Despite resistance training being well tolerated in most populations, only 14.6% of adults aged 75–84 years and 10.4% aged 85 years and older regularly participate in musculoskeletal strengthening activities as part of their leisure time (109).

Data from 25 randomized controlled trials in over 800 healthy adults aged 65 years and older (mean age of 70.4 years) provided preliminary findings of a dose-response effect for resistance training on muscular strength and morphology parameters (110). Performing a single weekly resistance exercise session has been reported to promote beneficial changes in muscular strength in older adults (111, 112). A recent review took a minimal-dose approach and reported that performing resistance exercise for at least 2 days weekly for 60 min or less appears to be appropriate for improving muscular function in older adults (113).

Detraining or reduced training studies provide important information on the exercise dose required to maintain physical fitness attributes once they are established. Once strength and muscle mass gains are achieved, a single weekly maintenance resistance exercise session of a sufficient volume and intensity appears to be effective in preserving skeletal muscle mass and strength in older adults (114). Exercise intensity may also play an important role in preventing physical detraining. One study demonstrated that muscular strength and physical mobility were preserved throughout 48 weeks of detraining following high-intensity resistance training, although this effect was not observed with low-intensity training (67). Thus, the minimal effective dose for increasing and then preserving muscle mass in older adults through resistance training is likely a very manageable exercise dose.

The optimal resistance training modality for enhancing muscular hypertrophy and strength/power outcomes in the oldest old has not been established. There is a growing body of literature assessing the safety and efficacy of resistance training approaches such as low-volume, high-intensity training and blood flow restriction training in healthy, frail, and diseased populations. While a few investigations have reported positive findings on muscular hypertrophy and strength/power outcomes in the elderly, further large-scale efficacy studies in the oldest old are required to determine the optimal individual dose of exercise to maximize the application of these training protocols in this population (115, 116).

CONCLUSION

Given the global changes in age demographics, the role of PA and exercise in preserving or improving physical function, health, and disease risk in the oldest old is a ripe area of future research.

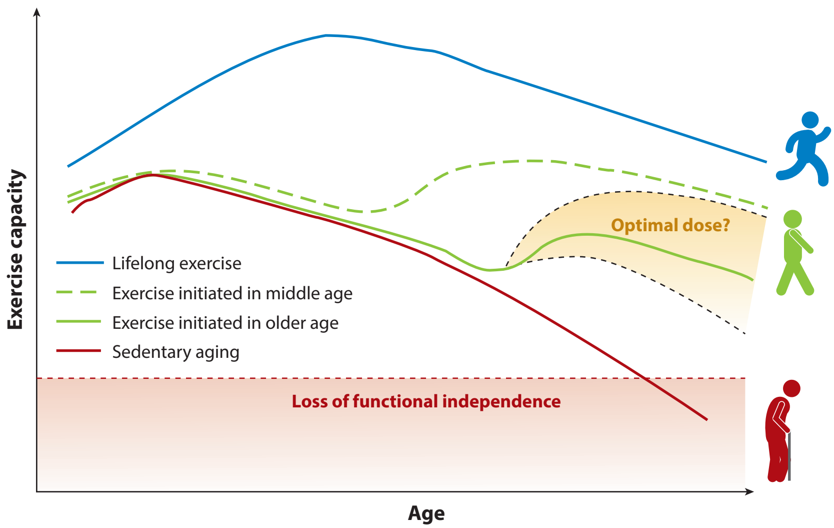

Figure 1

Even in the absence of disease, exercise capacity declines with aging. In many seniors, exercise capacity can fall to a level that results in a loss of functional independence (*solid red line*). Lifelong exercise consistent with or above current physical activity recommendations is associated with a greater exercise capacity even in the oldest old (*solid blue line*). Regular multimodal exercise training initiated in middle age results in cardiovascular and skeletal muscle structural adaptations and functional improvements (*dashed green line*). Exercise training started late in life (age >65 years) results in functional improvements despite only limited structural adaptations (*solid green line*). The training response (trainability) is likely influenced by the exercise dose performed (*yellow area*). The optimal exercise dose that improves and preserves exercise capacity in the oldest old remains unknown.

This research could contribute enormously to the translation of scientific and clinical information into notable lifespan health, function, and quality-of-life benefits for aged humans. **Figure 1** provides an overview of how prolonged and regular exercise training influences exercise capacity during adulthood.

Despite accumulating evidence of the favorable effects of aerobic and resistance exercise training on physical fitness and function in the oldest old, the types and dose of PA or exercise required to improve or preserve these outcomes are still unknown and require further investigation. It is also unclear whether the training dose required to improve or preserve health and physical performance outcomes differs in those with chronic disease, multiple comorbidities, or frailty compared to their healthier peers.

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