CONTINUING EDUCATION
for Physical Therapists

EXERCISE TRAINING-BASED INTERVENTIONS FOR THE OLDER ADULT

PDH Academy Course #PT-1803 | 3 CE HOURS

Course Abstract

The benefits of proper exercise dosing are multiple for older adults across the aging spectrum, and extend beyond physical functioning. This course examines the evidence pertaining to exercise prescription: it begins with a review of aging physiology and several screening methods; continues with a discussion of general exercise recommendations for older adults; and concludes with a look at either end of the aging spectrum, moving from frailty on the one hand to senior athletes on the other.

Approvals

To view the states that approve and accept our courses, visit https://pdhtherapy.com/physical-therapy/

Target Audience & Prerequisites

PT, PTA – no prerequisites

Learning Objectives

By the end of this course, learners will:

- ❑ Recall physiological changes relevant to the aging process
- ❑ Recognize assessments used to determine the functional ability of older adults
- ❑ Distinguish between evidence-based findings supporting flexibility exercise, strength training, power training, and endurance training, as well as multi-component exercise programs
- ❑ Identify evidence pertaining to exercise recommendations for older adults across the aging spectrum

Timed Topic Outline

I. Review of Aging Physiology (15 minutes)
Changes in Joint Structures, Changes in Bone, Changes in Muscle, Cardiovascular Changes, Pulmonary System Changes

II. Screening of Older Adults (15 minutes)

III. General Exercise Recommendations (75 minutes)
FITT (frequency, intensity, time, and type) Principles, Flexibility Exercise, Strength and Power Training, Endurance Training, Multi-component Exercise Programs

IV. Frailty and FITT Principles (30 minutes)
Exercise Prescription for Frail Older Adults

V. Senior Athletes and FITT Principles (30 minutes)
Exercise Prescription for Senior Athletes

VI. Conclusion, References, and Exam (15 minutes)

Delivery Method

Correspondence/internet self-study, with a provider-graded multiple choice final exam. *To earn continuing education credit for this course, you must achieve a passing score of 80% on the final exam.*

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Course Author Bio and Disclosure

Kerstin Palombaro, PT, PhD, CAPS, is Associate Professor and Community Engagement Coordinator at the Institute for Physical Therapy Education at Widener University in Chester, PA. She received her BS in psychology from St. Joseph's University, her Masters of Science in Physical Therapy from Columbia University, and her PhD in Physical Therapy from Temple University. She is a Certified Aging in Place Specialist.

Dr. Palombaro serves as an Associate Editor for the Journal of Geriatric Physical Therapy and a Member of the Editorial Board for the Journal of Physical Therapy Education. She has published peer-reviewed research on topics related to osteoporosis, hip fracture, and the impact of community engagement on student learning outcomes. The primary focus of her clinical practice is with older adults in home and home hospice settings. Her teaching in the areas of community health and health and wellness promotion emphasizes serving client through best practices in geriatrics.

DISCLOSURE: Financial – Kerstin Palombaro received a stipend as the author of this course. Nonfinancial – No relevant nonfinancial relationship exists.

Introduction

All human beings possess a certain amount of functional reserve and operate well below the upper limits of their functional capacity.[1] In older adulthood, as multiple organ systems deteriorate, some older adults begin to experience that the demands of their everyday life exceed their present functional capacity, resulting in disability.

Aging can be viewed as a continuum with successful agers at one end and frail older adults at the other.[2]

Endstage Frailty / Predeath	Prefrail (vulnerable) / Frailty Syndrome	Successful Aging / Resilient

Figure 1[3]

Successful aging emphasizes both physical and psychosocial strengths; successful agers can be thought of as the positive end of the aging spectrum.[2] There are various areas that impact successful aging, which can be thought of as the rule of fourths:[1] in short, aging can be viewed as being made up of disease, disuse, misuse, and physiological aging. Physiological aging is the decline of organ systems that occurs as age increase; various diseases such as cancer and osteoporosis also impact aging, as do sedentary lifestyles and health behaviors such as smoking and health conditions due to injuries.

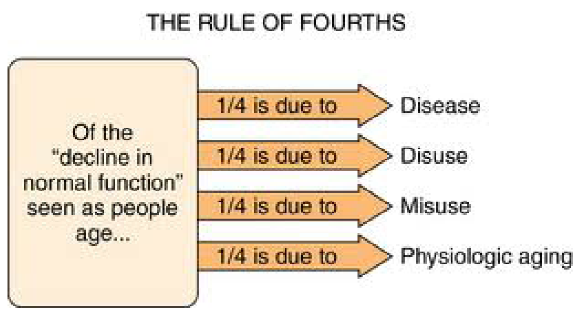

Figure 2: In the past, all of the decline in function that occurs between young adulthood and old age was called normal aging. We now know that approximately one fourth can be attributed to disease, one fourth to disuse (e.g., sedentary lifestyle, lack of mental stimulation), and one fourth to misuse (e.g., smoking, injuries from contact sports, and adverse effects of prescription and/or recreational drugs). Only about one fourth can be attributed to physiologic aging.[1]

Aging is associated with declines in physical activity and physical and psychological wellbeing.[3] Physical functioning can be thought of as a combination of muscle quality, muscle performance, and physical activity.[4]

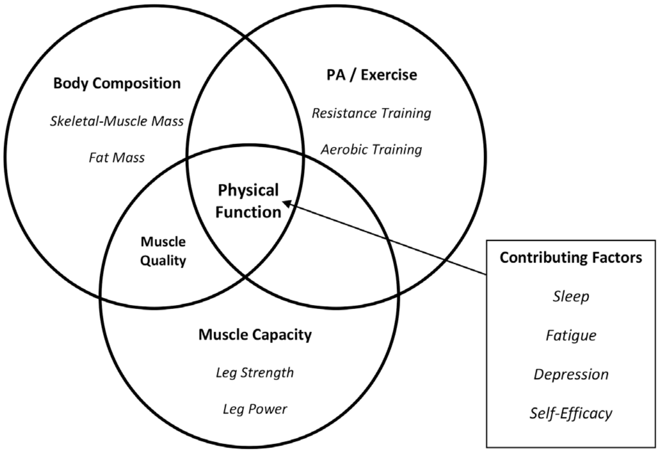

Figure 3[2]

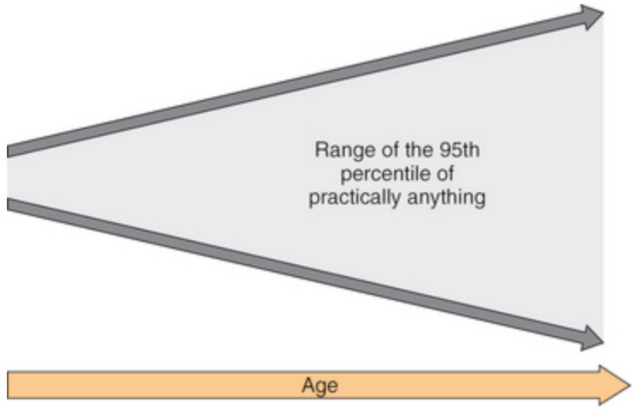

Figure 5[1]*: As people age they become more diverse. This explains why individualized care rather than protocol-based care is especially important in the geriatric population.*

Regular exercise promotes successful aging by impacting the physiological factors associated with aging.[3]

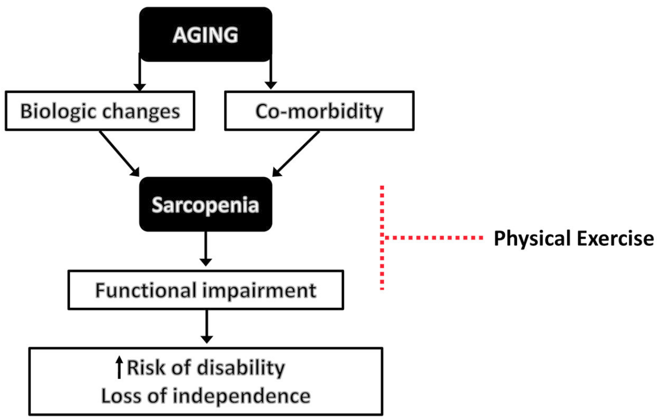

Figure 4: Simplified schematic of the development of physical disability among older adults and the potential of exercise to slow or prevent this development. The use of a dashed line highlights the variability of responsiveness and that standard exercise programs may be insufficient to prevent disability among several sub-groups of seniors.[4Page 29]

Proper exercise prescription can maintain or improve physical function by addressing muscle quality and performance and increasing physical activity; in turn, physical activity can address or counter disuse and misuse as well as mitigate the impact of disease.[3]

Aging is a largely heterogeneous event with functional ability not consistently matching chronological age.[5] As a result, exercise prescription must be tailored to the individual patient: there is no one-size-fits-all approach to addressing aging.

Review of Aging Physiology

In considering effective exercise training and physical therapy interventions for the older adult client, we will first briefly review the age-related physiological changes experienced by the older adult client.

Changes in Joint Structures

Older adults experience **connective tissue** changes. Connective tissue is the primary structural component of all joints, surrounding and infiltrating muscle.[6] Connective tissue forms the scaffolding that directs both the structure and function of each joint. At the cellular level, fibroblasts are basic connective tissue cells, which actively produce the extracellular matrix that is distinct in each joint structure.[7] Fibroblasts decrease in proliferation with aging.[8] The decreases in fibroblasts paired with decreased response to circulating growth factors impact both connective tissue repair and maintenance, which in turn causes the connective tissue of older adults to be less adaptive to load.[7] At the molecular level within connective tissue, we see decreases in cell turnover of and increasing crosslinkages between the proteins necessary for maintaining fluid content.[9] Collagen is the primary protein within connective tissue; elastin works with collagen to return structures to their pre-deformation shape.[10] The age-related changes within collagen and elastin increase stiffness and decrease the ability to absorb mechanical energy.[10] This can make joint structures more brittle and can result in higher rates of damage in response to repeated joint loads. While age-related changes to joint structures do occur, these can be influenced positively or negatively by a variety of factors including physical activity, injury, and pathology.[11-13]

In addition to connective tissue changes, **chondroid structures** undergo age-related changes. Chondroid structures are structures such as menisci, hip or shoulder labrum, articular cartilage and intervertebral discs. The main function of chondroid structures is to disperse loads across segments and decrease friction, thereby improving joint mobility. [14-17] Excessive torsional and compressive forces damage chondroid structures.[18-20] Damaged articular cartilage has limited healing ability and may lead to the development of lesions.[18-20] Articular cartilage calcification is another typical age-related change, which compromises both the viscoelastic properties and load-absorbing capacity.[21,22] Intervertebral discs also experience age-related changes as the nucleus becomes more fibrotic and the annulus more disorganized; cracks in both may develop.[23-25] Decreased disc height results from decreased water content in the disc.[24,25]

Fibrous structures in the body include ligaments, tendons, and joint capsules. With aging, these experience increased stiffness and reduced elasticity.[26-29] Both the cross sectional area and tensile strength of these structures decrease with age.[26,30]

Physical therapists need to be mindful of the changes in connective tissue, condroid structures, and fibrous structures when making an exercise prescription for the aging adult. For example, while an active older adult may tolerate a repeated load such as a leg-press, a sedentary older adult with osteoporosis may experience damage to connective tissue with the same exercise. While condroid structures such as menisci and articular cartilage experience changes independent of osteoarthritis, some evidence exists that the prevalence of meniscal tears is higher in those with osteoarthritis.[31] Thus there may be pathology such as spinal stenosis or osteoarthritis occurring concomitantly with the changes in the condroid structures. The reduced elasticity of ligaments and tendons may lead to tears and avulsions versus sprains and strains.[32,33]

Changes in Bone

Bone metabolism refers to the process of bone turnover. Osteoblasts are the cells responsible for the production of new bone cells.[34] Osteoclasts are the cells responsible for the resorption of osteocytes, or older bone cells.[34] The parathyroid hormone, calcitonin, and the hormonal form of vitamin D, or calcitriol, work together to regulate bone metabolism. With low serum calcium, parathyroid hormone is secreted which activates osteoclasts. As serum calcium rises, calcitonin is secreted which activates osteoblasts. With low serum calcium, calcitriol works with parathyroid hormone to encourage osteoclastic activity; with higher serum calcium levels, calcitriol works with calcitonin to encourage bone deposition.[35]

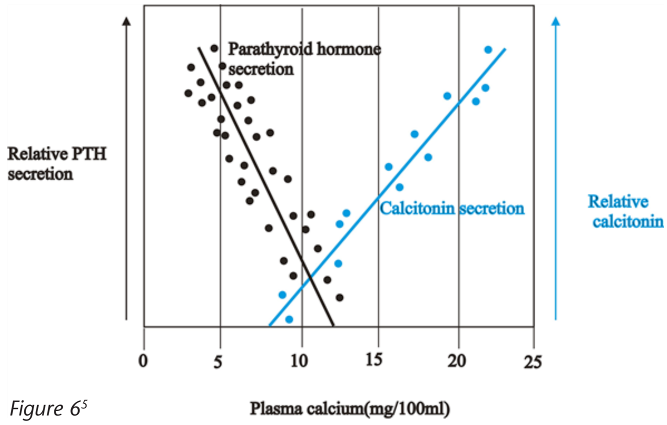

Figure 6[5]

In healthy adult bone metabolism, bone formation is equal to bone absorption. However, as aging occurs, the bone turnover cycle becomes unbalanced. Beginning at age 30, there is a shift in which osteoblastic activity decreases.[36] Adults over the age of 30 begin to lose bone at a rate of .5 to 1.0% per year.[36] Thus bone production is slightly outpaced by bone resorption. In healthy adults this loss of bone can be mitigated by physical activity, which can increase bone production at a rate of 1.0% per year.[37,38] Women will also experience an additional shift in bone balance at menopause, when the decrease in estrogen is accompanied by an increase in osteoclastic activity.[39-41] In general, men will lose about 30% of trabecular bone and 20% of cortical bone in their lifetimes.[42,43] Women lose 50% cortical and 1/3 trabecular bone in theirs.[42,43] Subchondral bone, which is a special type of trabecular bone, provides structural support to the articular cartilage. With typical aging, the thickness and density of subchondral bone decreases in a non-uniform fashion.[44] With this loss of bone, bone loses the ability to absorb loads.

Osteoporosis is a pathological loss of bone in response to aging and/or menopause. Osteoporosis is clinically defined by both the World Health Organization and the National Osteoporosis Foundation to be a bone mineral density T-score more than 2.5 standard deviations below young, normal reference ranges for the spine, hip or radius.[45] ***Osteopenia*** is defined as a bone mineral density T-score 1.0 to 2.5 standard deviations below young, normal reference ranges.[46] Non modifiable risk factors for osteoporosis include a family history of osteoporosis; Asian or Caucasian race; being female; being post-menopausal.[47,48] Modifiable risk factors for osteoporosis are nutrition, particularly adequate calcium and vitamin D intake; physical activity level; smoking; low body mass; and excessive alcohol consumption.[47,48] As of 2010, approximately 10.2 million Americans aged 50 years or older had osteoporosis and 43.4 million more had osteopenia, with women representing the majority of those cases.[49] Thus it is highly likely that on top of normal age-related bone changes, the older adult clients seen by physical therapists may have osteoporosis.

Changes in Muscle

Muscle experiences several changes with aging. The first is a **reduction in muscle mass**.[50] This muscle atrophy is related to impaired skeletal muscle protein synthesis with aging. The decline in muscle cross sectional area is considered to be due to the loss of muscle fibers, particularly Type II, fast twitch fibers.[50] Along with the atrophy of muscle tissue, fat and connective tissue infiltrate the muscle belly.[51] Thus, girth measurements will not show the actual reduction in muscle mass. ***Sarcopenia*** is considered to be a universal aging phenomenon characterized by a progressive loss of skeletal muscle fibers and fat free mass. It is operationally defined as skeletal muscle mass > 2 standard deviations below the healthy young adult mean.[52] Sarcopenia results in a decline in muscle strength, with decreases from .8-5% annually, depending on gender and muscle group.[53,54] Additionally, muscle power declines as age increases.[55] Sarcopenia and osteopenia appear to be interrelated;[56-58] the stresses muscle places on bone decline with increases in sarcopenia. Some degree of sarcopenia appears to be inevitable with age, as older athletes also experience strength declines as compared to younger athletes.[50] As sarcopenia progresses from normal to greater than two standard deviations below normal, the likelihood of functional impairment increases.[59] A recent meta-analysis found the world-wide prevalence of sarcopenia to be 10% in both males and females.[60]

Within aging muscle we see both **changes in the size of muscle fibers** and a **loss of muscle fibers**. When we consider atrophy of muscle fibers, **Type II**, fast-twitch muscle fibers experience atrophy, while **Type I**, slow twitch fibers do not.[61,62] The reason for this pattern of atrophy is that Type I fibers are in relatively regular use, while Type II muscle fibers are rarely recruited.[63] Thus, patterns of disuse atrophy target Type II fibers. This will have implications on tasks requiring power and force production in the older adult, which will be addressed later.

There are also reported changes at the level of the **motor unit**. In the average person, the total number of motor neurons decreases with age, with a 25% observed average loss from the 2nd to 10th decade.[64] With this decrease comes an increase in the total number of muscle fibers innervated by a single motor unit.[65-68] The net result is that the older adult client may recruit more muscle initially, thus fatiguing faster than clients in other age categories.

Cardiovascular Changes

There are several age-related structural and functional changes of the heart that will relate to exercise dosing. The left ventricular posterior wall thickens approximately 25% with aging.[69] Just as within joint structures, there is an increase in collagen crosslinkage, resulting in a stiffer pericardium.[70-73] Amyloid protein deposition occurs in the myocardium of about 1/3 of older adults resulting in dysfunction.[70-72] Just as in skeletal muscle, adipose tissue infiltrates cardiac muscle tissue, rendering fattier heart tissue, which may in turn lead to disturbances in the electrical conduction system of the heart.[74]

Ventricular hypertrophy results from changes in systolic blood pressure and an increasingly dilated and less flexible aorta, which increases the volume of blood present in the ascending aorta.[75] The workload demands thus increase on the heart. The cardiac muscle is becoming stiffer, decreasing the ability of the left ventricular wall to expand during diastole,[75] resulting in reduced and/or delayed filling. During the systolic phase of the cardiac cycle, the left ventricle also contracts less and ejects less blood, causing a reduction in stroke volume.[73,75] The left atria also increases in size due to the delayed filling of the left ventricle, increasing the workload demands on the left atria.[70,71,76] These increases in workload demands can impact the initial endurance presentation of older adults. While at rest, cardiac output remains unchanged; however, exercise tolerance is impacted due to an average 8% reduction in maximum aerobic dynamic performance capacity per decade after age 30.[77]

In addition to the aorta, the walls of all of the arteries and capillaries become thicker, stiffer, and less flexible. These changes are accompanied by an increase in the diameter of the arteries and decreases in arterial wall compliance.[70-72] Lipids accumulate in the arterial walls.[70-72] The walls of veins thicken and the valves within the veins become stiffer.[70-72] The efficiency of venous smooth muscle contractility is reduced and the responsiveness to the autonomic nervous system is less rapid.[70-72] These venous changes may be of concern for the possibility of thrombus formation and thus it is critical for the physical therapist engaging in proper exercise dosing to determine whether, for example, calf pain is due to delayed onset muscle soreness or a deep vein thrombosis.

The structural changes impact function. The most measurable change that physical therapists see on a daily basis is the rise of blood pressure, primarily the systolic measurement.[78] Blood pressure can be seen as a measure of cardiovascular efficiency; the elevated blood pressure at rest seen with aging is the result of both decreased aortic compliance and increased peripheral resistance.[70-72,78] While these changes are typical with aging, they can be modified through diet and exercise. Additionally, even a 10mmHg elevation in blood pressure increases the risk of coronary heart disease.[79]

The **electrical conduction** system also experiences changes. The number of pacemaker cells in the sinoatrial node is less than 10% the number of a young adult,[80] resulting in an inverse linear relationship of decreasing maximum heart rate with aging.[81] This decline in maximum heart rate, along with a decline in stroke volume, impacts cardiac output, which in turn influences the cardiovascular response to exercise (**VO_{2max}**).[81] This decline in VO_{2max} diminishes exercise capacity or aerobic performance. [82] The decline in maximum heart rate occurs in all older adults and results in decreased heart rate variability; aerobic exercise can increase heart rate variability in older adult populations.[83-85] The nerve conduction system of the heart experiences increases in elastin and collagen and fat accumulates around the sinoatrial node.[81,86] The bundle of His and bundle branches experience an infiltration of fat.[87] Structures such as the atrio-ventricular node and the bundle branches may be damaged or destroyed by left-sided heart calcification.[81] These can result in changes of pacing that may make it necessary to rely on other methods of assessing exercise tolerance such as the Borg Rating of Perceived Exertion.

Pulmonary System Changes

The muscular, skeletal, and cardiovascular changes seen with aging carry over into the pulmonary system. Strength and endurance decline in the ventilatory muscles,[88,89] with the diaphragm experiencing a 20-25% reduction in strength.[88,89] These reductions serve to increase the **work of breathing**. However, all motor units remain intact throughout the lifespan as resting breathing recruits slow-twitch motor units, strenuous exercise recruits fast twitch motor units, and all motor units are recruited during activities such as coughing.[88,89]

Total lung capacity, vital capacity, and residual volume increase from birth through late adolescence.[90,91] As height decreases with aging due to changes in the vertebral column, the size of the thorax is reduced.[91] Increasing collagen crosslinkages in the ribs and sternal cartilage result in a more rigid thorax. These changes require greater muscle force to achieve a change in interthoracic pressure, reducing lung volume capacity. This results in reduction in maximal static respiratory pressures of 15% to 20% from age 20 to 70, with a significant reduction experienced by age 55.[88,89]

A generalized and uniform reduction in the number of elastic fibers in alveolar ducts is present from age 50, which becomes significant by age 80.[92-94] These changes result in decreased elastic recoil of the lung. The ducts and alveolar openings also become slightly dilated.[92-94] This may be responsible for the loss of elastic recoil in older adults, leading to a progressive increase in residual lung volume and functional residual capacity.[95-97] The retention of volume means that the chest wall is held in a position of partial inspiration, shortening the resting length of inspiratory muscles and flattening the diaphragm.[98] This reduces the contractile force of the inspiratory muscles, which is overlaid on a stiffer chest wall that is more difficult to displace.[98] The bronchi and brionchioles become more rigid and experience thickening of the mucosal layer; both increase resistance to flow.[99,100] All of these changes increase the work of breathing, resulting in increased oxygen cost for any level of activity. Thus, appropriate endurance dosing is necessary to improve older adults' activity tolerance.

Gas exchange is impaired with aging. With the alveolar changes, uneven ventilation and circulation occurs.[90,92-94,101] The result is **ventilation/perfusion mismatch** with inspired oxygen distributing in the apices of the lung and blood flow continuing to be greatest at the bases. This along with a reduction of alveolar capillary surface area results in decreased diffusion of oxygen. A large portion of inspired oxygen is consumed by the ventilatory muscles due to the increased work of breathing in older adults, reducing the total amount of oxygen available to other muscles.[102,103] Additionally, the ability of the muscles to extract the remaining oxygen decreases as well.[104]

In the older adult, oxygen supply may not be able to meet the demand. The impairments in systems yield decreased efficiency (work performed/oxygen used). This may place older adults at risk for decreased physical activity and the ability to perform instrumental and activities of daily living independently. Proper exercise dosing can serve to counteract these changes in fitness as increasing efficiency allows individuals to perform tasks such as ADLs with reduced energy expenditure.[105]

Screening of Older Adults

In order to provide proper exercise prescription and dosing, physical therapists must perform a thorough examination and evaluation. Multiple screening tools and outcomes measures exist to assist physical therapists that work with older adults. Assessing various physical performance measures will provide the physical therapist with a snapshot of an older adult's functional ability. While the patient interview may capture self-reported deficits, these objective physical measures serve to provide a more complete picture. One study examining self-reported disability in adults age 60 and older found that the young old (mean age of 60) reported difficulty in or inability to walk a quarter mile only when they reached a more severe level of objectively measured impairment than the older old (mean age of 76). In the same study, this also held true for older adults of higher socioeconomic status versus lower socioeconomic status and higher educational level versus lower socioeconomic status.[106] In contrast to self-report measures, valid and reliable standardized assessments can be sensitive to change, can characterize higher levels of function, and can even out cross-cultural differences.[107]

VanSwearing and Brach[108] discuss the three considerations that should be made when selecting a test or measure. The first consideration is the appropriateness of the tool or measure being used for the patient population in question. For example, if a tool has been created for use with community-dwelling elders, then it would be inappropriate to use with older adults who reside in nursing homes. The second consideration is the practicality of the measure. Issues surrounding practicality include the length of time it takes for a test or measure to be administered; the amount of experience needed by the person administering the test or measure; whether a specific test or measure requires formal training; what type of equipment is needed; the format of the test or measure; the method of scoring: whether a test can be hand-scored or is computer- or app-based; and the format of the resulting measurement.[108] The final consideration is the psychometric properties: namely, is a test or measure reliable and valid. Reliability can be thought of as consistency, or the degree to which two measures are alike.[108] Validity can be thought of as accuracy, or that the test or measure should relate to other measures.[108] These considerations are taken into account with each of the physical performance measures discussed below. The five physical performance measures listed as screening tools represent a broad array of tests and measures available to the physical therapist, and are recommended by the American College of Sports Medicine (ACSM).[109] Together or separately, these tests provide a picture of the functional abilities of older adults in order to best address the needs of individual patients.

At its simplest, **gait speed** is an important tool for assessing the overall physical functioning of an older adult. Gait is comprised of both the progression of the center of gravity through space and dynamic postural control.[110] Gait speed, or velocity, is a measure of this progression.[111] Habitual gait speed slows with aging, particularly after the 6th decade of life[112-114] Reported gait speeds for safe street crossing within the timing of a traffic light range from 1.2 m/sec to 1.32 m/sec.[115,116] However, the average habitual gait speed of older adults in the United States is reported as lower than this speed. Chui and Lusardi[117] reported self-selected walking speeds for community-dwelling women aged 70-79 as 1.34 m/sec, aged 80-89 as 1.05 m/sec, and aged 90-99 as 0.80 m/sec. The reported speeds for men aged 70-79 were 1.55 m/sec, aged 80-89 were 1.30 m/sec, and 90-99 were 1.09 m/sec. Bohannon[118] reported slightly slower gait speeds using National Health and Nutrition Examination Survey data. Data reported for women were as follows: aged 60-69 1.00 m/sec; aged 70-79 0.92 m/sec; and 80 and older 0.76 m/sec. Data reported for men were as follows: aged 60-69 1.12 m/sec; aged 70-79 0.95 m/sec; and 80 and older 0.84 m/sec.

There are a variety of established distances and instructions for gait speed assessment reported in the literature.[119] Moreover, while some physical therapists may test only habitual gait speed, fast gait speed may be tested as well.[119] Computerized walkway systems exist to calculate gait speed.[120,121] However, typically a stopwatch is used to time an individual walking a measured distance at their normal speed and/or as quickly as possible, with a set distance for acceleration and deceleration built into the assessment.[122-124] Gait speed is then calculated in meters per second (m/sec). A more complete description of measurement of gait speed will occur in a subsequent section that discusses the Short Physical Performance Battery.

Gait speed assessment is reported as having reliability[119,124] and validity.[119,125] The minimal detectable change, or change required to be considered change beyond error, for habitual gait speed is reported as .094 m/sec for patients with Alzheimer's disease;[126] .11 m/sec for older adults walking at intermediate speeds;[127] .14 m/sec for older adults walking at fast speeds;[127] 0.08-0.11 m/sec for patients with Chronic obstructive pulmonary disease (COPD);[128] 0.09 m/sec for patients with Parkinson's disease;[129] 0.16 m/sec in patients in cardiac rehabilitation;[130] 0.13 m/sec for patients in short term rehabilitation;[131] and 0.08 for patients post hip fracture.[132] Walking speed is predictive of frailty;[133] risk of hospitalization;[134,135] mortality;[131,134,135] mobility disability;[131] impaired cognition;[136] and self-care ability.[131,137-139] Gait speed is also predictive of falls;[134] VanSwearing and Brach calculated 0.56 m/sec as the cut score that was able to successfully discriminate between fallers and non-fallers.[108]

Another assessment measure useful in directing exercise prescription is the **Short Physical Performance Battery (SPPB)**.[140] The SPPB is a combination of three reliable and valid tests of balance, walking speed, and lower extremity strength that have been previously described in the literature.[141-144] This test is easy to perform in a variety of settings, but was designed for use in community-dwelling older adults' homes. The length of administration is approximately 10-15 minutes; the only equipment required is a stopwatch, a rigid measuring tape, and a straight-backed chair.[140]

Testing begins with a Romberg progression. The tester first demonstrates each balance test position. The patient is asked to get into the position while the therapist supports the patient's forearm. The patient indicates when he or she is ready and the therapist releases forearm support and begins timing. Timing is stopped when the patient comes out of position; requires support; or 10 seconds elapses, whichever comes first. The testing sequence begins with semi-tandem balance, where the patient places the heel of one foot against the great toe of the other foot. If the patient is able to maintain this position for 10 seconds, the balance test is progressed to tandem stand, with the heel of one foot directly against the toes of the other foot. If the patient is unable to maintain semi-tandem then the balance testing progresses to side-by-side stand with the feet placed together. The timing is identical to semi-tandem stance. The patient may choose which foot assumes the forward position for tandem and semi-tandem testing.

The 8-foot (2.44-meter) walk test requires twelve feet (3.6 meters) of walking space.[140] A rigid measuring tape is opened up to indicate 8 feet. Two additional feet of space are required on either end of the 8-foot walkway to allow for acceleration and deceleration. The patient is instructed to "walk at your normal speed." Timing is begun when the patient reaches the beginning of the measuring tape and is stopped when the other end of the measuring tape is reached. The patient performs two trials of walking and the faster walk is recorded. The patient can use his/her usual assistive device.

The chair rise test is used to test functional lower extremity strength.[140] A straight-backed chair is placed against the wall. The patient is instructed to sit on the chair and fold his/her arms across his/her chest. The patient is instructed to try to stand up from the chair while maintaining the arm position. If the patient is able, he/she is instructed to sit back down. The patient is then instructed to stand up and sit down five times as quickly as possible. Timing begins when the therapist says "go" and ends at the standing position of the fifth stand.

The SPPB was first administered to 5,174 people aged 71 and older living in Boston, MA, New Haven, CT, and rural Iowa.[140] Categories of performance for each test were created by dividing the times for each test into those unable to complete the test, those falling in the 25th, 50th, 75th, and 100th percentile, with accompanying scores of 1 through 4 for each percentile and 0 for unable. A summary score is calculated by adding the scores from each test. Summary scores range from 0-12, with higher scores indicating better performance.

Predictive validity is documented for the SPPB. Summary performance scores are associated with death; those with scores falling within the 25th percentile are more than twice as likely to die as those in the 75th percentile.[145] A decline in nursing home admissions has also been demonstrated with increasing summary performance scores.[145] The SPPB is associated with mobility disability;[146] older adults scoring 7 or higher are eight times less likely to have no disability with activities of daily living than those with scores of 6 or lower.[145] Poorer performance on each component of the SPPB has been found to be correlated with poorer performance on instrumental activities of daily living.[147] The SPPB is demonstrated to be a stronger predictor of risk of hospitalization than gait speed alone.[148] SPPB scores of less than 8 are associated with poorer self-reported health status.[149]

The **six-minute walk test (6MWT)** assesses aerobic capacity and endurance via the distance walked in six minutes.[150] It requires a straight 30-meter, level walkway. The walkway should have the endpoints clearly marked with cones, as well as 3-meter intervals marked along the hallway. The only other equipment required is a stopwatch. Patients must be able to walk independently with or without an assistive device. Patients should sit for 10 minutes in a chair near the starting point of the test for vital sign assessment. Incentive spirometry is often performed at this point as well. There is a standardized set of instructions prior to the test in which the Borg rating of perceived exertion (RPE) and the modified Borg scale for breathlessness are explained. Additional instructions are standardized and include the patient being instructed that they will walk for 6 minutes as far as possible; that they can slow down and rest in a standing position if they need to; but that they should resume as soon as possible. The physical therapist demonstrates one lap of the walking course. Instructions are standardized for the start, at one-minute intervals, with 15 seconds to go, and at test completion. The physical therapist counts the laps completed and the distance traveled on the last lap. If the physical therapist uses habitual gait speed versus the fastest speed possible, this should be documented as well. Vital signs, incentive spirometry, RPE and breathlessness ratings are recorded immediately at the conclusion of this test. The test may be stopped prior to completion for a number of reasons including the participant asking to stop the test, chest pain, dyspnea that is not tolerated, and leg cramps.

The 6MWT has reported reliability[151-157] and validity.[152,155,157,158] The minimal detectable change is reported for the following populations: older adults (58.21 meters),[159] patients with osteoarthritis (61.34 meters),[154] patients with subacute stroke (60.98 meters),[159] chronic stroke (34.37 meters),[160] COPD (54 meters),[161] Alzheimer's disease (33.47 meters),[162] and Parkinson's disease (82 meters).[163] The minimal clinically important difference, or change that is meaningful to a patient, is also reported for older adults and patients post-stroke (50 meters)[159] and patients with COPD (54 meters).[164] Gender-specific, age-related norms are reported for healthy community-dwelling older adults who walk independently without an assistive device.[151] The reported mean distance walked for males is age 60-69 years (572 meters), age 70-79 (527 meters), and age 80-89 (417 meters). The reported mean distance walked for females is age 60-69 years (538 meters), age 70-79 (471 meters), and age 80-89 (392 meters). In general older, shorter and heavier people have shorter reported distances.[165]

Another screening tool of use with older adults, particularly those who achieve the highest score on the SPPB, or those who cannot complete the chair rise test portion of the SPPB, is the **Senior Fitness Test** also referred to as the **Functional Fitness Test (FFT)**.[166] This screening tool assesses performance on tasks associated with physical function in independent older adults 60 and older. Functional fitness is defined by the creators of this test as "having the physiologic capacity to perform normal everyday activities safely and independently without undue fatigue."[166p.133] The test consists of a 30-second chair stand test to measure lower extremity strength; an arm curl test to measure upper extremity strength; a chair sit-and-reach test to measure lower body flexibility; a back scratch test to measure upper extremity flexibility; a choice of the 6-minute walk test or 2-minute step test to measure aerobic capacity; an 8-foot up and go test to measure motor agility and dynamic balance; and body mass index via assessment of height and weight.

The Senior Fitness Test has reported reliability and validity.[166] Normative data for all tests have been reported for men and women for the following age groups: 60-64, 65-69, 70-74, 75-79, 80-84, 85-89, and 90-94.[167,168] Additionally, there are thresholds for each test item to identify if an older adult is at risk for loss of physical function.[168,169] A comprehensive training manual is available for purchase for a modest price.[169]

The four tests described above are free (aside from the aforementioned training manual for the Senior Fitness Test). All involve minimal equipment that is readily available to the physical therapist.

The **Continuous Scale Physical Functional Performance (CS-PFP) Test**,[170] the **Continuous Scale Physical Functional Performance Test-10 (CS-PFP10)**,[171] and the **Wheel Chair Physical Functional Performance Test (WC-PFP)**[172] are three variants on the same test. The CS-PFP consists of 16 tasks that are related to activities of daily living and which are divided up into tasks of low, moderate, and high difficulty.[170] Low difficulty tasks are carrying a weighted pan a distance of one meter; pouring water from a pitcher to a cup; putting on and taking off a jacket; and placing and removing a sponge from a shelf. Tasks classified as moderate difficulty are sweeping the floor with a broom and dust pan; opening and walking through a fire door; transferring clothes from a washer and dryer to a basket; making a bed; vacuuming; placing a strap over a shoe; and picking up four scarves from the floor. Tasks of high difficulty include carrying a weighted bag up and down a simulated bus stop; sitting and standing up from the floor; climbing stairs; carrying groceries a distance of 70 meters; and the 6MWT. The tasks are scored by the length of time it takes to complete each task, and the weight carried or height reached for applicable items. The scores are converted to percentages so that the adjusted scores range from 0-100; higher scores indicate higher functional levels. The CS-PFP10 uses 10 of the original 16 items.[171] The items eliminated from the CS-PFP10 are the water-pouring task, the door-opening task; the bed-making task; vacuuming, placing a strap over the shoe; and the bus stop simulation. Tasks included in the WC-PFP are carrying a weighted pan; pouring water; putting on and taking off a jacket; placing and removing a sponge from a shelf; pulling open and wheeling through a fire door; transferring clothes; placing a strap over the shoe; picking up scarves; and carrying groceries. In addition to these tasks, additional tasks are transferring from a wheelchair to a standard-height chair and a 6-minute wheel test.[172]

All three versions of the CS-PFP require extensive equipment, and the length of time required to complete these tests ranges from 30-60 minutes.[170-172] Several days of training are required to use this test, which costs a few thousand dollars between the participant training cost, the cost of materials, and the data analysis software and license required to adjust the scores. This may make the test impractical for individual therapists; however, facilities may decide to invest in this training as the test can be performed on a wide range of patients: adults 18 and older as well as those who use a wheelchair for mobility. These tests are reliable and valid.[170-172] Normative data has been reported for older adults,[173] people with Parkinson's disease,[174] and manual wheelchair users.[172] Additionally scores of 57 and above on the CS-PFP indicate independence in older adults.[170]

General Exercise Recommendations

The ACSM makes the case that for healthy older adults, the physical activity recommendations are similar to younger adults, with an additional emphasis on balance, agility and proprioceptive training for older adults who are at risk for falls.[109] Additionally, the ACSM notes that the modified Borg Rating of Perceived Exertion should be used to assess exercise intensity with ratings of 5-6/10 indicating moderate intensity and 7/10 or greater indicating vigorous intensity.[109,175]

FITT principles need to be considered when making an exercise prescription for any client: FITT stands for frequency, intensity, time, and type.

For exercise targeting aerobic capacity, the frequency should be 3-5 days/week of moderate to vigorous intensity, for 30-60 minutes per day, which can be broken up into several smaller bouts of exercise of at least 10 minutes of duration.[109] The lower end of the range of frequency and time apply to vigorous activity. The ACSM recommends that for any aerobic activity, which does not excessively stress the musculoskeletal system,[109] physical therapists should use their clinical judgment and consider their patients' current physical activities and interests when making an exercise prescription.

For resistance training, the ACSM recommends 2 or more days/week.[109] The intensity should be light for those new to resistance training; light would be considered to be 40-50% of 1 repetition maximum (1RM); this can be progressed to moderate intensity once the older adult adapts to resistance training. Those not new to resistance training should engage in moderate to vigorous intensity at 60-80% of 1RM.

A full treatment of assessing intensity for strength training will occur in a subsequent section. Time and type recommendations are for 8-10 exercises that target major muscle groups at 1-3 sets of 8-12 reps for each exercise. These exercises could be traditional progressive resistive exercises, could use bodyweight for resistance such as sit-to-stand or floor-to-stand transfers, or functional activities such as stair climbing.

Flexibility exercises should occur on 2 or more days per week, and should occur just to the point of tightness, not pain.[109] Stretches should be held for 30-60 seconds and should emphasize slow, controlled movements.

Flexibility Exercise

All older adults regardless of where they fall on the aging spectrum should engage in **flexibility exercises**, as flexible joints maintain the proper length-tension relationship of muscles. However, evidence in support of flexibility exercises to treat or prevent injuries is limited. One Cochrane review found that regardless of whether stretching occurred prior to, during, or after an exercise program did not result in a meaningful reduction of muscle soreness.[176] Another Cochrane review found no evidence that flexibility exercises prevented soft-tissue injuries of the lower extremity in runners.[177]

Flexibility exercises may be more important for less active and frail individuals. One study examined the impact of flexibility exercises on gait parameters on healthy sedentary older adults. The intervention group performed a home program ankle and hip stretching for eight weeks. Both hip extension and plantarflexion range of motion significantly increased in the intervention group. Habitual gait speed also significantly increased at the end of the study in the intervention group. This study suggests that flexibility exercises could promote functional improvements in older adults.[178] This is supported by the finding that upper extremity flexibility as measured by the CS-PFP10 was correlated with age ($r = -0.365$, $p < .008$) and physical functioning on the SF-36 ($r = 0.424$, $p < .001$) and the SF-36 physical function component score ($r = 0.451$, $p < .001$) in a sample of older adults in their 90s.[179] However, weak correlations have been found between the chair sit and reach test of lower extremity flexibility for the FFT and physical component summary scores of the SF-36 ($r = 0.28$, p , .01), with flexibility not entering into the regression equation to predict physical component summary scores.[180] And while another study found that the odds of older adults walking greater than 6500 steps per day were significantly higher in those with better performance on the lower extremity flexibility test in the FFT, those odds were not particularly high (OR = 1.10, CI = 0.94, 1.09, $p = .03$).[181] Promoting flexibility could be an important key for older adults to maintain or improve their present functional mobility and preserve quality of life, but should be included as part of a comprehensive program that emphasizes strength and aerobic capacity training.

In cohorts of senior athletes, flexibility exercises may increase range of motion, but may not have an impact on function. Both a stretching and a strengthening protocol were found to increase lower extremity strength and range of motion over time as compared to controls in a sample of older runners.[182] Participants were randomly assigned to a group, with the intervention taking place over eight weeks. Despite changes in strength and flexibility, no changes in running biomechanics were found.

There is evidence in the literature in support of various flexibility programs. One recent review discusses Tai Chi, a practice of slow, sustained movement, as having a positive impact on measures such as flexibility, balance, and parameters such as gait.[183] Pilates exercises and static stretching were found to significantly improve trunk and hip flexibility, while Pilates also significantly improved ankle flexibility in a sample of older women.[184] One study randomly assigned sedentary older adults to a traditional stretching and strengthening program or a Hatha yoga program.[185] Both groups met three times a week for eight weeks. Functional fitness was measured via the Senior Fitness Test and balance was assessed via the four-square step test. The yoga program was found to be as effective as a traditional exercise program in improving functional fitness measures that included flexibility.

Another study found that passive stiffness in a straight leg raise stretch is significantly reduced in static stretches held at a constant torque versus at a constant angle.[186] Calf muscle stretching improved ankle dorsiflexion range of motion in a sample of older women.[187] One multi-component study examined the impact of group exercises on flexibility, balance, strength, and aerobic capacity.[188] Participants engaged in five to seven minutes of stretching, 15 minutes of strength training, a slow walk and 15-20 minutes of balance and coordination training three times a week for a minimum of 36 weeks. Flexibility as measured by the sit-and-reach test, significantly increased in older adults aged 65-74 and all women, but these increases were not maintained after three months of detraining.

A recent systematic review and meta-analysis found no effect of stretching on muscle or tendon properties.[189] However, effects were noted for a tolerance of stretching and reductions in muscle stiffness. The study noted that flexibility programs should be longer than eight weeks of duration to achieve changes beyond that of the sensory level. A combination of stretching and strengthening exercises demonstrated significant pain reduction and improvements in physical functioning in adults with hip osteoarthritis.[190] Muscle stiffness has been found to be a significant predictor of physical disability in older adults with osteoarthritis (r^2 =0.43, p < .001),[191] and thus a flexibility program may be useful in older adults who are experiencing joint stiffness due to age-related joint stiffness.

Pilates, yoga, Tai Chi, and traditional static stretching exercises all appear to reduce muscle stiffness and promote range of motion. Physical therapists should ask their older adult clients which mode of flexibility exercises they prefer. Discussing the ACSM flexibility exercise guidelines with older adults regardless of where they fall on the aging continuum and prescribing a program that is of interest to them will help to promote musculoskeletal health.

Strength and Power Training

Older adults benefit from **strength training**, which is training the muscles to generate force. However, **power training**, or training the muscles to generate force quickly, should not be neglected in older adults. Both strength and power training are accomplished through **resistance training**.

High quality intervention studies work all major muscle groups. Examples of upper extremity exercises include lat pull down, chest press/bench press, arm curls, and triceps press.[192-194] Examples of lower extremity exercises include the leg press, leg extension, hamstring curls, and hip adduction and abduction.[192-194] Abdominal crunches and back extension exercises may also be included.[193] Progressive resistive exercises typically use machines or free weights, although elastic bands with sufficient resistance can also be used.

The first step in proper dosing for resistance training is the establishment of the one **repetition maximum** or **1RM**. The 1RM is the maximum amount of weight that can be lifted once with proper form.[195] The 1RM should be established for all muscle groups that will be trained after a warm-up period. The weight is gradually increased until the patient can only lift the weight for one repetition without compensatory movements.[195] The assessment of 1RM does not result in injuries,[196] nor does it significantly raise blood pressure in older adults.[197] However, it may take as many as eight to nine familiarization sessions to obtain a consistent 1RM measurement in untrained older adults as compared to untrained young and middle-aged adults.[195,196] Additionally, there may be other instances in which traditional 1RM testing is not a viable option including setting constraints such as home care with the concomitant limits of available equipment or the short-term stays associated with acute care; physical and intellectual disabilities and cognitive impairments that may limit assessment; and pain.[198]

Another approach to assessing 1RM is the use of the RPE.[175] Studies using the RPE as a proxy for 1RM testing in older adults have reported varying results. One study found that older adults using anchored RPE ratings underestimated their 1RM for knee extension using RPE;[199] another showed that RPE ratings of 14-17 accurately corresponded with loads of 70-90% of 1RM in older adults doing a chest press task.[200] Studies have noted poor agreement[198] between 1RM and RPE, as well as over-estimating RPE relative to 1RM.[201] RPE has also been found to be useful to create prediction equations to estimate initial 1RM and training-related changes.[202] The use of anchored measures of the modified Borg through asking a patient to assign a rating to a maximal voluntary contraction as well as being asked to assign a rating to sitting quietly appears to assist older adults in the use of RPE.[199] Providing some element of orientation to the RPE scale appears to be an important element if using this as a proxy for 1RM testing.

One final approach to proxy measurement of 1RM for lower extremity strength may be the 30-second sit to stand test, which was found to be useful in older adults with COPD.[203]

Progressive resistive training, through proper exercise dosing, is necessary to target age-related sarcopenia, reduce body fat and improve lean body mass, and to maintain or improve functional mobility in older adults.[204,205] One meta-analysis found that progressive resistive exercises increased habitual gait speed by .11 m/sec and fast gait speed by /12 m/sec with a concomitant large effect size.[206] In addition to changes in muscle strength, documented changes in balance, reduction in falls, and mobility and improvements in cognition, depressive symptoms, and quality of life have been noted in the literature.[204,205,207-209] Positive changes in metabolic markers including cholesterol, blood glucose, and C-reactive protein have also been noted; older adults with longer experience engaging in progressive resistive training experience greater changes.[210] One recent meta-analysis found a positive effect of strength training that was progressed to 70-80% of 1RM on gait speed.[211] Strength training may impact longevity as well. One cohort study examined 15 years of longitudinal data from the National Health Interview Survey. Less than 10% of the 29,975 older adults enrolled in the study met the ACSM guidelines of strength training at least twice a week; however, those who met the recommendations for strength training had 46% lower odds of all-cause mortality.[212]

Strength Training:

The most recent Cochrane review examining the effectiveness of progressive resistive exercise training on physical function in older adults was performed in 2009.[213] The review included any randomized clinical trial that included older adults with a mean age of 60 and that had progressive resistive exercise as the primary intervention. Isometric-only strength training and interventions that included other types of training such as balance and aerobics were excluded. There were 6700 participants across 121 trials included in this review, with sub-analyses including smaller numbers of participants from fewer trials depending on the outcomes. For resistance training studies compared to a control group, moderate-to-large benefits were found for strength, timed up-and-go, and timed chair rise. Significant, but modest effects were found for improving gait speed and decreasing pain level. Small, significant effects were found for progressive resistive training on aerobic capacity with positive impacts on VO_{2max} and the six-minute walk test and for decreasing disability. No effects were found for the physical function domain of the SF-36 or SF-12, timed walk, vitality, and death. Additional comparisons were made examining high versus low progressive resistive training dosage. Moderate-to-large effects were found for lower extremity strength favoring high intensity training. Small effects were found for vitality favoring the high intensity group. No effects were found for physical function, pain, or aerobic capacity. Progressive resistive training was found to have a significant benefit over aerobic training on strength. No significant difference between aerobic training and progressive resistance training were found on physical functioning, gait speed or pain, although the treatment benefit for all but physical functioning favored the strength training groups. 68 of the studies included in this Cochrane review provided information about adverse events. There were only a few serious adverse events, none of which appeared to be related to the intervention. The typical non-serious adverse events were musculoskeletal in nature. The clinical bottom line of this Cochrane review is that high intensity strength training appears to be safe and can impact strength, aerobic capacity, physical functioning and pain.

Ahtiainen et al[214] performed a retrospective analysis of 10 high-quality resistance-training randomized controlled interventions, all of 20-24 weeks duration enrolling a total of 287 participants, that they had conducted. The purposes of their study were to determine if there were age- or sex-specific changes in strength and muscle size, and to determine the proportion of participants in their study who were low-responders to resistance training. The authors divided the studies up into those with participants younger than 45 years of age, those with participants age 45-60, and those with participants 61 years of age and older to examine age-related differences. The authors also examined differences between males versus females. The authors found 1RM and 1RM/body mass significantly increased in all groups from pre-test to post-test, regardless of age or sex. Both low and high responders were represented in both sex and across all age categories. Low responders came from all studies and represented 6.7% of the sample; high responders, with strength changes greater than one standard deviation from the mean, represented 13.8% of the sample. Muscle size increased significantly from pre-test to post-test, regardless of age or sex. Non-, low and high responders were represented in both sex and across all age categories for muscle size gains. Non-responders represented 14.6%, low responders represented 29.3% and high responders (defined as greater than one standard deviation gain in muscle size) 12.2% of the total sample. Overall, only 3.2% of participants were low responders for both muscle size and strength gains. This evidence suggests that regardless of the age of the participant or their sex, we can be confident that muscle strength gains are likely in our patients.

Many studies examining strength-training dosages enroll younger participants, making it challenging for the physical therapist to apply study findings to older patients. One study sought to examine the impact of high- or low-volume strength training on neuromuscular adaptations in the upper and lower extremities of older women. Twenty healthy women aged 60-74 were randomized to a high- or low-volume strength training group.[193] Both groups performed two nonconsecutive sessions a week for 13 weeks, with the low volume group performing one set of each exercise and the high volume group performing three sets. All major muscle groups were targeted. The number of repetitions per set varied according to the phase of the intervention and ranged from 20RM at the beginning to 12-15RM in the middle, and 10RM at the end of the intervention period. At the completion of the study, both groups demonstrated significant increases in maximal dynamic strength as measured by knee extension and elbow flexion 1RM and lower body maximal isometric strength, maximal electromyographic activation, muscle thickness and muscle quality. However, there were no significant between-group differences, suggesting that physical therapists could assign a progressive resistive exercise program of one set of sufficient intensity to achieve positive results with their patients. This is supported by the findings of a 12-week study utilizing three different dosage intensities for leg press and leg extension in older adults.[215] All participants engaged in three training sessions per week. The high-intensity group performed 2 sets of 10-15 repetitions at 80% of 1RM. The low-intensity group performed one set of 80-100 repetitions of 20% of 1RM. A low-intensity plus group performed one set of 60 repetitions at 20% of 1RM and then one set of 10-20 repetitions of 40% of 1RM. The high-intensity and low-intensity plus groups both improved in 1RM as compared to the low intensity group. However, the high-intensity group had significant changes from pre- to post-intervention in 6MWT distance, five times sit-to-stand and 30 second sit-to-stand performance and gait speed, which the low-intensity plus group only improved in the five times sit-to-stand and 30 second sit-to-stand. While the two groups were not significantly different from each other and while the high-intensity group did not significantly improve relative to the low-intensity group, the functional improvements with a less time-consuming strength-training regimen are pertinent to physical therapy practice. Less volume at higher intensity may be a more efficient exercise prescription for our clients.

Parmenter et al[192] conducted a 6-month, blinded, randomized, controlled study in which participants with symptomatic peripheral arterial disease were randomized to a high-intensity, progressive resistive strength training group, a low-intensity, non-progressive strength training group, or a control group that consisted of usual care. The high-intensity group started out performing three sets of eight repetitions for all major muscle groups at 50% of 1RM and by session four worked up to 80% of 1RM; intensity was reassessed every two weeks using the Borg RPE, ensuring that participants were working at ratings between 15-18. The low-intensity group began at 20% of 1RM at then was increased by 2% at each training session until 30% of baseline 1RM was attained. At that point, the load ceased to be progressed. The usual care group was instructed to walk at their normal speed for up to 30 minutes, three times a week. The high-intensity strength-training group had significant increases in 6MWT distance and whole body strength as compared to the other groups. Other changes reported were independent of group assignment. Changes in onset of claudication during the 6MWT over time were significantly associated with changes in calf muscle endurance; changes in 6MWT distance over time were significantly associated with changes in hip extensor endurance.

One study examined the impact of resistance training on body composition, blood pressure, blood glucose, insulin, C-reactive protein, and cholesterol in 22 post-menopausal women aged 60 and older.[194] Participants in the study performed progressive resistance training targeting all major muscle groups three times a week for 12 weeks. Three sets of eight to twelve repetitions were performed at each session. Exercise dosing was achieved using the modified Borg RPE scale, with participants exercising at an RPE of six for the first four weeks, and achieving ratings of eight by the final four weeks. These dosages would approximate 60-80% of 1RM. Significant reductions in BMI and waist circumference; total cholesterol, low-density lipoprotein, and total cholesterol divided by high-density lipoprotein; and blood glucose and insulin were observed. The effect sizes reported were insignificant to low for body composition (Cohen's *d* range 0.054-0.283), low (Cohen's *d* range 0.307-0.374) for cholesterol, and moderate for blood glucose and insulin (Cohen's *d* range 0.475 to 0.567). Peak knee extension torque significantly increased with reported moderate effect size (Cohen's *d* range 0.512 to 0.588). While the effect sizes reported were low to moderate for metabolic and cardiovascular risk profile factors, providing a foundation of progressive resistance training that could be continued may show further reductions in this risk profile over time.

In a double-blinded, randomized controlled trial enrolling 100 adults aged 55 and older with mild cognitive impairment, Mavros et al[207] examined the impact of high-intensity progressive resistive exercise training paired with cognitive training, compared to high-intensity progressive resistive exercise training alone versus two sham groups that mimicked the treatment groups over a 6-month period. The progressive resistive exercise training consisted of small group exercise programs twice a week for 60-100 minute sessions with intensities within 80-92% of participants' current strength. Cognitive training occurred via a computer exercises designed to impact areas such as memory and executive function. Significant improvements in cognitive functioning, strength, and aerobic capacity occurred as a result of high-intensity progressive resistive training. The authors found that the strength gains mediated the changes in cognitive functioning, while the changes in aerobic capacity did not. Resistance training has also been found to improve executive functioning in older adults.[216]

Alterations in the delivery of strength training can also be useful in effecting change in physical performance. Eckardt examined the impact of lower extremity resistance training on unstable surfaces in older adults aged 65-80.[217] The participants were randomized into one of three groups: a group engaging in traditional resistance training using machines; an unstable resistance training group that performed the same exercises but with an unstable surfaces between the participant and the floor or the participant and the machine; and a third group that used free weights and an unstable surface. Unstable surfaces included equipment such as Bosu balls, wobble boards, and dyna-discs. All training took place twice a week over 10 weeks; 1RM was reassessed every few weeks for all groups. The training sessions were 60 minutes long and included 10 minutes at low resistance on a stair climb machine for a warm-up. All groups exhibited similar improvements in muscle strength, power, and balance. However, the training load for the free-weight, unstable group was significantly lower. Strength training using free weights and unstable surfaces may help improve physical performance measures in older adults who are unable to exercise at the higher intensities required with weight machines. However, the use of free weights is itself an unstable exercise; older adults unfamiliar with weight training may require supervision for this type of resistance training. One systematic review and meta-analysis did find small effects for strength and power using resistance training on unstable surfaces and large effects on balance.[218] This evidence supports the use of at least some unstable strength training as part of an overall progressive resistance program to improve balance in older adults.

The above studies focus on traditional concentric training; however, older adults can also gain increased strength through eccentric training. One common way to perform eccentric training using weight machines is by doing the concentric movement bilaterally and the eccentric movement using only one limb.[219] Older adults, through the preservation of eccentric muscle contraction, can train with greater resistance eccentrically.[220,221] One study examined the impact of concentric versus eccentric exercise of the knee extensors in men aged 60 to 76.[222] The eccentric load began at 10% and progressed to 100% of 1RM; the concentric group progressed from 50% to 100% of 1RM. Both groups trained once a week for 12 weeks. The 30-second chair rise, maximal knee extension contraction and cholesterol significantly improved in the eccentric group as compared to the concentric group. These results corroborates through earlier work by Mueller et al who found moderate-intensity eccentric training significantly increased thigh muscle mass and isometric knee extension strength as compared to conventional concentric training.[223]

Another study examined the impact of a three times weekly concentric versus eccentric training plan of the knee extensors for 14 weeks.[224] The conventional training group performed open-chain knee extension and leg press exercises two sets of 10 repetitions at 80% of 5RM. The eccentric training group performed both exercises, but with the researcher lifting the load for the knee extension exercise and with an electric motor lifting the leg press into full knee extension. For eccentric training, the participants paused for 0.5 seconds prior to eccentrically lowering the load. At the end of the 14 weeks, the concentric group had significant increases in concentric torque and the eccentric group had significant increases in eccentric torque. Muscle thickness significantly increased in both groups, muscle fascicle length significantly increased in the eccentric as compared to the concentric group, and the pennation angle significantly increased in the concentric group, which has been found to increase muscle contraction velocity.

Power Training:

In addition to strength training, power training is important in the older adult. The need to generate force quickly can be seen in functional tasks such as accelerating walking speed when a traffic light begins to change or in climbing stairs. Power training is important to emphasize, as power declines before strength in the older adult and these declines occur 3-4% more per year as compared to muscle strength.[225,226] Sarcopenia was related to power in one study examining jump test performance in persons aged 55 to 75 years old.[227] Those participants classified as having sarcopenia had significantly lower jump power and jump velocity as compared to those without sarcopenia, demonstrating deficits in power-generating capacity due to decreases in appendicular skeletal muscle mass. Studies focusing on traditional progressive resistive exercises find that peak power, muscle activation, and physical performance measures do not improve with this modality[228] However, power training, or high-speed strength training, has been reported in the literature as more effective than traditional high-intensity strength training at slow speed at promoting the generation of rapid force production and in improving physical performance characteristics.[229] Additionally, increased strength in muscles trained and improvements in functional capacity are reported.[230] Thus, power training should be a part of an exercise prescription for older adults.

Physical therapists can use progressive resistive training as well as functional tasks to address power deficits in the older adult. Two functional tests addressing power could also become part of an intervention to address power. In the **Stair Climb Power Test**, patients are instructed to ascend a flight of 10 stairs as fast as they can and are allowed to use a handrail for safety if necessary. Patients stand at the base of the steps and begin climbing when a tester says, "Ready, set, go." Timing begins at the word "go" and stops when the patient has both feet on the top step. Power is calculated with the formula Power = [(body weight in kg) x 9.8 m/s^2 x (stair height in meter)]/(time in seconds) where the height of the full flight of stairs is 1.985 meters.[231] The Stair Climb Power Test can differentiate between young, middle-aged, and older adults.[232] The **Four-Step Stair Climb Power Test** uses a typical four-step set found in inpatient and outpatient physical therapy gyms. The instructions are the same and the stair height measurement is 0.762 meters.[233] Both tests yield valid and reliable measurements.

Ramirez-Campillo et al[234] examined the impact of a low-speed versus high-speed progressive resistive exercise program in older women. The program, which worked all major muscle groups, took place three times a week for 12 weeks. The low-speed group completed all three sets at 75% of 1RM. The high-speed group did one set each at 45, 60 and 75% of their 1RM, to expose them to the range of dosage that optimizes power. A control group performed no resistance training. Both resistance-training groups had significant creases in strength, power and physical performance measures as compared to the control group. However, the high-speed group had significant differences at post testing in a 2 kg medicine ball throwing task, 10-meter walking sprint and an 8-foot up-and-go task. The first two of these tasks could be considered power tasks and the third could be considered to have elements of both power and strength.

Sayers and Gibson conducted a study to determine if peak power shifted to lower external resistances after 12-weeks of high-speed power training as compared to low-speed resistance training.[235] 72 older adults were randomized to the two training groups or a control group that performed the warm-up and stretching exercises that the other two groups were performing; 64 older adults completed the study. Both training groups used a leg press and a knee extension exercise three times a week for 12 weeks. The high-speed power-training group performed three sets of 12-14 repetitions of 40% of 1RM; the concentric phase was performed quickly with a one-second pause at full range and the eccentric phase of the movement performed over two seconds. The low-speed strength-training group performed three sets of 8-10 repetitions at 80% of 1RM; the concentric phase was performed over 2-3 seconds with a one-second pause at full range and the eccentric phase of the movement performed over two seconds. Both the high-speed power-training group and the low-speed strength-training group experienced significant increases in 1RM and muscle power as compared to the control group. The high-speed power-training group was the only group to experience a change to a lower external resistance at which peak power was produced. This has a functional implication, as peak power at lower resistance is important for a variety of functional tasks including increasing gait speed or taking a quick step in response to an external balance perturbation.

Using the same protocol as above, Sayers and Gibson examined the impact of high-speed power training on braking speed in 89 ambulatory older adults 65-90 years old.[236] The high speed strength training group had greater peak power and peak power velocity across the range of 40-90% 1RM as compared to the control group, while the low-speed strength training group had a greater peak power and peak power velocity compared to the control group only at 70-90% of 1RM. The high-speed power-training group improved 15.3% in reaction time to the viewing of a visual stimulus to taking the foot off the accelerator in a driving simulator, the low-speed strength-training group improved 2.7%, and the control group performance decreased by 2.2%. The RPE differed between the two training groups. The high-speed power-training group rated the leg press as "light" to "somewhat hard" and the knee extension as "somewhat hard" to "hard." The low-speed strength-training group rated the leg press as "somewhat hard" to "hard" and the knee extension as "very hard." These results indicate improved performance in a functional task that older adults encounter frequently, as well as perception of decreased effort in exercises.

In a controlled trial that examined differences between high-speed power training against a control group, participants with a mean age of 71.3(6.6) engaged in power training three times a week for twelve weeks.[237] The participants performed leg press and seated knee extension exercises for three sets of 14 repetitions at 40% of 1RM. The exercise protocol had participants performing the concentric phase of the movement as quickly as possible, pausing for one second, and then performing the eccentric phase over the course of two to three seconds. At the completion of the study, two separate analyses were performed, one between the control and the power training group and one analyses between those with a low-velocity, self-selected concentric phase, those with a high-velocity, self-selected concentric phase, and the control group. In the analyses between the control group and the power-training group, no significant differences were found in habitual or fast gait speed or timed up-and-go time. SPPB scores and 1RM scores were higher in the power-training group than in the control group at post testing. In the analyses examining low- versus high-velocity contractions, there were no between-group differences for habitual walking speed. The self-selected, high-velocity contraction group had significantly greater improvement in fast gait speed as compared to both groups, in TUG score as compared to the low-velocity group, and SPPB score and 1RM as compared to the control. The self-selected low-velocity group also had significantly greater 1RM as compared to the control. This study demonstrates the need for sufficient speed of contraction in order for changes related to power to occur.

Power training does appear to have advantages over high-intensity, progressive resistance training. Marsh et al found that in comparison to strength training, power training resulting in a doubling of lower extremity power measures and similar strength increases.[238] When training at similar intensities, power training results in significantly greater increases in muscle thickness.[239] Even studies that show similar strength and power gains between traditional progressive-resistance exercise and power training suggest that power training has an advantage, as the changes occur with lower total volume of work.[240]

The ACSM recommendations are that all adults engage in progressive resistive training at least twice a week and work all major muscle groups.

Progressive resistive training can be performed to address both strength and power, as discussed in this section. However, there may be times during which older adults' training is interrupted due to illness, travel, or other life events. Detraining does occur, and is accompanied by declines in strength, muscle fibers, and muscle mass; however, strength measurements remain consistently higher than prior to the start of strength training.[241-243] Power measurements remain higher than strength measurements after periods of detraining,[244] indicating that functional capacity can be preserved during bouts of no exercise. However, both strength and power training help to preserve improvements in physical performance during periods of training, and both types of exercise result in strength and power gains during periods of retraining.[245] Physical therapists should assure their patients that skipping a day, or even a few weeks, of training will not result in a spiral of functional loss. Additionally, resuming strength training will be building upon a foundation that is stronger than the baseline at which patients started.

Endurance Training

Aerobic capacity and **endurance training** is an important component of an exercise prescription for the older adult. In addition to improving cardiovascular endurance and flexibility, aerobic training can address muscle parameters as well.[246] Aerobic training can improve skeletal muscle fiber size, muscle protein synthesis, and glucose sensitivity.[246-249] Additionally, inflammation and oxidative stress can be reduced through aerobic training.[247-249] Aerobic exercise can also improve cognition: moderate intensity continuous aerobic training can improve executive functioning, and high intensity interval training (HIIT) can improve information processing speed.[216]

Aerobic training is typically either continuous in nature or comprised of high-intensity interval training (HIIT) interspersed with short periods of rest (HIIT appears to impact muscle metabolism).[246] It can be adjusted to the older adult's interests, abilities, and potential physical impairments. Walking can easily be performed on walking trails, treadmills, or in shopping malls. Cycling can be adapted from a traditional bicycle to a recumbent and from stationary to traditional models depending on ability. Swimming and water aerobics can be suggested for older adults with access to pools, both to address interests as well as to use the buoyancy of water to reduce stress on painful joints.

One study examined the impact of two different types of walking interventions on endurance capacity in older adults.[250] Older adults were randomly assigned to either a Nordic walking group that utilized aluminum walking poles, or an XCO walking group which used hand-held weights that have an internal movable mass. Both groups had four weeks of technique instruction followed by 12 weeks of twice-weekly training with sessions lasting 60 minutes. Participants were initially trained at 60% of their peak heart rate during a stress test and were progressed to 85% of that value. Walking speed was progressed from 1.0 to 1.8 m/s. At the end of the 12 weeks of training, no significant between-group differences were noted for heart rate during the training sessions, total distance covered, or walking speed. VO_2 and energy consumption were measured at 5 different speeds that ranged from 1.0 m/s to 1.8 m/sec on a 400-meter track at speed. The Nordic walking group experienced a significant 5% reduction in heart rate from the pre-test to the post-test. A 32% reduction in lactate threshold was noted for the Nordic walking group at the first three speeds of 1.0 m/s, 1.2 m/s, and 1.4 m/s; the XCO group significantly reduced their lactate threshold by 40% from speeds of 1.0 m/sec to 1.6 m/s. Significant differences in energy consumption were noted for both groups from pre-test to post-test; the Nordic walking group experienced a significant decrease in energy expenditure at 1.0 m/sec and the XCO group experienced a significant decrease in energy expenditure at 1.6 m/s. Both groups thus experienced improved efficiency through endurance training at an appropriate intensity for older adults, but with a frequency lower than ACSM-recommended guidelines. Physical therapists prescribing walking with trekking poles or XCO hand weights at the ACSM recommended frequency, intensity, and time may see improved aerobic capacity and endurance in their clients.

Marques et al[251] conducted a study comparing the efficacy of resistance exercise to aerobic exercise in improving strength and balance in older women. Both groups met three times weekly over 32 weeks; total time exercising was 60 minutes which included a 10-minute warm-up and a 5-minute cool-down. Resistance exercises targeting major muscle groups were progresses from 50-60% of 1RM to 80% of 1RM. Aerobic exercise was progressed from 50-60% of heart rate reserve and was progressed to 85% of heart rate reserve. Both groups were also compared to a wait-list control group. Balance was assessed via the up and go test measured over 8 feet and the one-legged standing test using the non-dominant leg on a force platform. Knee flexion and extension strength were measured. Magnitude-based statistics were used, as opposed to traditional between-group difference statistics, in order to detect changes in physical performance. Both groups improved on these measures as compared to the control group. Balance improved on all measures across small to large magnitude and across the majority of measures with almost certain probabililty in both groups as compared to the control. The difference between the aerobic and resistance training groups was unclear. Resistance training was favored over aerobic training for knee strength as compared to the control group, with an almost certain improvement noted for resistance training over a possible improvement for the aerobic training group. The resistance-training group had a greater magnitude as compared to the aerobic group, with improvement noted as very likely to be greater in the resistance-training group. This finding is affirmed by another study by Marques et al,[252] which found similar improvements in balance between aerobic exercise and resistance training, but which found only resistance exercise impacted bone mineral density. Thus, physical therapists can be confident that aerobic training or resistance training can achieve positive balance outcomes, but that strength gains are more likely to be seen by a resistance-training component.

Bellumori et al examined older adults who engaged in a cycling intervention as compared to a control group.[253] The cycling intervention consisted of two 30-minute sessions in which participants cycled at low resistance at a preferred cadence and then did 10 x 20-second high-speed cadence intervals followed by 40 seconds of rest. A significant group by time interaction was found for TUG time and knee extension strength. Additionally, upper extremity strength increased, which the authors feel points to improvements in central drive as the upper extremities were untrained. Another cycling study engaged 15 older adults who were randomized to a HIIT group or a no-exercise control group.[254] The cycling group performed 12 weeks of three days a week of 4 x 4 min at 90-95% of peak heart rate. After 12 weeks the NKA protein, which maintains muscle membrane excitability and contractibility, showed statistically significant increases specific to Type II muscle fibers.

One study compared aerobic exercise to an attention-control group in older adults with low socioeconomic status.[255] The training group was progressed from walking 10 to 40 minutes three times a week for 16 weeks at 60-75% of heart rate maximum and a Borg RPE ranging from 12-14. The control group received nutrition education every two weeks. Outcomes measures were the Medical Outcomes Study Short Form Health Survey (SF36), the SPPB, the Physical Performance Test, the CS-PFP10, leg extension strength, and peak aerobic capacity. The aerobic training group significantly improved on the CS-PFP10 score and peak aerobic capacity, with change in physical function being strongly correlated to the change in peak aerobic capacity ($r = 0.85$). Regression analysis revealed that the change in aerobic capacity accounted for 87% of the variance in the change on the CS-PFP10. The aerobic training group had significant improvement on the physical function domain of the SF-36 as compared to the control. This study demonstrates the impact that effectively dosed aerobic training can have on both actual and perceived physical functioning in older adults.

Evidence has demonstrated that aerobic exercise can result in skeletal muscle hypertrophy.[256,257] One study enrolled healthy, sedentary men aged 70-80 in either a control group or a group that trained on a cycle ergometer for 30-45 minutes at 50-70% of VO_{2max} three times a week over 16 weeks.[258] The cycle training was followed by a four-week detraining period. Leg strength, power and muscle mass as well as VO_{2max} all significantly improved as compared to the control group; however, only the VO_{2max} gain persisted after the detraining period. Unlike high-intensity resistance training, aerobic training does not result in persistent strength and power gains through detraining periods. Physical therapists should be cautious in providing an aerobic-only training program for older adults who may engage in detraining periods due to events such as illness or hospitalization or leisure activities such as travel.

Reichert et al[259] examined the impact of a continuous-versus interval-training deep water running intervention on blood pressure and physical fitness parameters in older adults aged 60 to 75. Both training programs were twice a week for 28 weeks; training sessions were 45 minutes in duration with approximately 15 minutes of the session devoted to warm-up and cool-down. Both groups had training cycles broken up into four-week increments. The continuous-training group exercised at the following Borg RPE per four-week cycle: 13, 15, 16, 13, 15, 16, and 17. The interval-training group performed the first four-week cycle and weeks 13-16 at 10 x 2 minutes with a Borg RPE of 15 and 1-minute rest intervals in between. Weeks five to eight and 17 to 20 were performed at 6 x 4 minutes at a Borg RPE of 17; weeks nine to 12 and 21 to 24 at 7 x 4 minutes at Borg RPE of 17 with 30 seconds rest. Weeks 25-28 were performed at 12 x 2 minutes at Borg RPE of 18 with 1-minute rest intervals. At the end of the 28 weeks, both groups showed significantly improved performance on all areas of the Senior Fitness Test, with the exception of upper extremity flexibility, which had a group interaction only with the interval group demonstrating increased flexibility. Both groups improved significantly in systolic and diastolic blood pressure; the interval-training group had significantly lower diastolic blood pressure than the continuous-training group at both time points. This points to evidence for either continuous or interval training as effective interventions to improve strength, flexibility, endurance and blood pressure parameters in older adults.

Another study compared HIIT to moderate-intensity continuous training using an upper- and lower-extremity cycle ergometer; a control group was also tracked.[260] The HIIT group performed four intervals at 90% of peak heart rate for four minutes, followed by three minutes at 70% of peak heart rate for 25 minutes. The moderate intensity group worked continuously at 70% of peak heart rate for 32 minutes. Both groups engaged in exercise four times a week for eight weeks. Peak VO_2, ejection fraction, and insulin resistance significantly improved in the HIIT group, but did not improve in the other groups. Body weight and composition were unchanged in all groups.

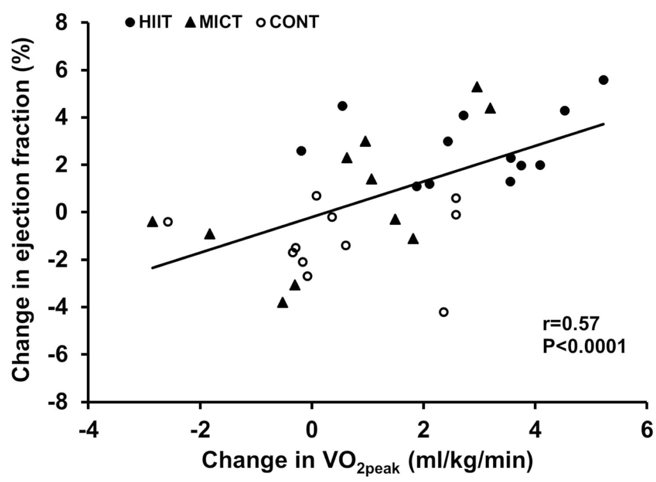

Figure 7: Relation between the change in peak oxygen consumption (VO2peak) and the change in left ventricular ejection fraction. CONT=non-exercise control; MICT=moderate-intensity continuous training; HIIT=high-intensity interval training. [6]

A walking study that compared four times weekly HIIT to moderate-intensity, continuous training to a control reported significant increases in isometric knee flexion and strength, significant increases in peak aerobic capacity in walking and cycling, and significant reductions in resting systolic blood pressure in the HIIT group but not in the continuous training or the control groups.[261] This study included middle aged and older adult men and women. This evidence points to HIIT as a preferred training option for aerobic exercise dosing.

One issue with sedentary older adults and exercise prescription can be motivation to exercise. Knowles et al[262] examined the impact of low-volume, HIIT on health-related quality of life, exercise motivation, and aerobic capacity in older men. The study enrolled 25 sedentary men with a mean age of 63(5); sedentary was defined as people who had no formal exercise for a period of at least 30 years. The study also enrolled 19 lifelong exercisers with a mean age of 61(5); a lifelong exerciser was operationally defined as being a highly active regular exerciser. This group had a mean weekly exercise of 281(144) minutes; 12 of these participants were national competitors in Masters-class sports. The sedentary group engaged in a six-week, pre-training period in order to bring their activity level up to the ACSM guidelines of 150 min/week of moderate intensity and to get their training target to 60-65% of heart rate reserve. Both groups engaged in HIIT cycle-ergometer training during the second period; training occurred every five days with 6 repetitions of 30 second sprints at 40% of peak power output with three minutes of rest at low resistance in between. The groups were measured at pre-test, prior to the second training period, and at post-test. Both groups had significant increases in VO_{2max}; the sedentary group had moderate gains achieved during their pre-training session and large gains after the HIIT session. The sedentary group had significant increases across all domains except "role limitations due to emotional problems" and the lifetime exerciser group had significant increases in the pain domain on the SF-36. A group by time interaction was noted for two SF-36 domains; the lifetime exercise group was had significantly higher scores on the general health domain at baseline and on the physical functioning domain at baseline and at the end of the HIIT session. Motivations for exercising were measured by the Exercise Motives Inventory II. Controlling for baseline levels of motivation, HIIT training increased motivation to a greater extent in the sedentary group. Thus, HIIT training is a useful and effective intervention for sedentary older adults to increase motivation, health-related quality of live and VO_{2max}.

Multi-Component Exercise Programs

Given that both endurance and resistance training cause muscular and cardiovascular changes, exercise programs combining both modalities may be the most effective to preserve functional capacity in older adults.[263] **Multi-component exercise programs** were found to improve habitual gait speed by .09 m/sec with a reported moderate effect size and fast gait speed by .12 m/sec with a large effect size.[206] A combination of circuit-training resistance exercise and aerobic training at 60% of maximum heart rate three days a week significantly improved blood pressure, leg, and handgrip strength in post-menopausal women as compared to a control group.[264] Twice-weekly multi-component exercises are as effective as strength training in improving strength, power, walking speed, and dynamic balance. One three times weekly for 12 week combination program focusing on strength, aerobic training, and flexibility improved cognitive abilities in older adults including processing speed, executive functioning, and memory.[265] Including endurance and strength training in exercise prescription for the older adults is recommended by the ACSM; including both modalities on the same day can be tolerated by this population and may improve both cognitive and physical parameters.[266]

One study used a cross-over design to examine the effectiveness of a multi-component program on functional fitness in older adults.[217] Older adults ages 70 and older were randomized into an immediate or delayed training group. The delayed group acted as a control and the immediate training group engaged in six months of training. At the six-month mark, the immediate training group ceased exercise and the delayed group engaged in the same training program for six months. Both groups were then followed for an additional six-month, no-exercise period. The exercise intervention for both groups consisted of daily walking for aerobic training, with some sessions monitored and others performed individually; aerobic training started at 50% of heart rate reserve and was progressed to 70% of heart rate reserve. Strength sessions took place twice a week, with resistance exercises addressing all major muscle groups. The first three months focused on strength with two sets of 12 repetitions at 50% of 1RM; the next three months focused on power with the intensity changed from 10RM to 6RM across the three months. Weeks 9 and 18 of the power training sessions were recovery weeks, with only endurance training occurring. At the end of the first six months, the immediate intervention group had significantly better SPPB scores, times on the 8-foot up-and-go test, knee extension strength, and 6MWT distance. The immediate intervention group increased their daily physical activity by 13%, while the delayed group decreased this time by 14%. In the second phase, the delayed intervention group experienced similar changes as the immediate intervention group; the immediate intervention group maintained all of their positive physical performance changes over this time. Both groups maintained increased physical activity during the 6-month follow-up phase. This study demonstrates the positive changes that a multi-component exercise program can have on both physical performance as well as physical activity behaviors in older adults.

One study compared resistance training to a combination of endurance and resistance training to impact muscle in older adults.[267] The training groups met for 21 sessions over seven weeks. The resistance-training group performed a leg press exercise for 70% of 1RM for 4 sets of 12 repetitions. The number of sets was progressed to 6 sets of 8 repetitions as the 1RM increased. The combination group performed endurance training at a cadence of 60-65 for 30-60 minutes. The majority of sessions were at 60% of VO_{2max}, with sessions 12-20 performing 6-8 repetitions of 2-minute intervals at 95% of VO_{2max}.This was followed by the resistance training exercise. Both training groups took a protein supplement within 20 minutes of exercise completion; the combination group had a carbohydrate component added to the supplement. Both groups demonstrated similar increases in 1RM; however, VO2max only increased in the endurance-training group. Both groups experienced increases in the area of Type I muscle fibers; the resistance training group increased the area of Type II muscle fibers.

A study compared combination resistance and endurance training, to resistance-only training, to a control group in healthy older adults.[268] The exercise groups met three times a week for 10 weeks. The endurance-training group performed 20-30 minutes of continuous aerobic activity on a cycle ergometer. The combination group performed a whole-body, resistance-exercise circuit with weight adapted to participants' 1RM. After the fifth week, two circuits were completed. The combination group performed the resistance circuit followed by the identical cycle ergometer protocol of the endurance group. Both training groups had significant improvements in BMI, waist and abdominal circumference, and blood pressure; the combination group experienced significant reductions in fat mass. Another study examining the impact of resistance training versus combination training in older adults with hypertension found that both types of training reduced BMI and inflammatory markers.[269]

Sequencing of exercises is another issue that some researchers have studied. Cadore et al looked at whether endurance training prior to strength training or the inverse would have a greater impact on strength in older men.[270] Subjects were randomly assigned into one of two training sequence groups; some participants were measured twice in the four weeks prior to the study to serve as a control group. The strength exercises worked all major muscle groups and were progressed from 18-20 repetitions of 1RM to 6-8 repetitions of 1RM across 12 weeks. Both groups increased upper and lower body strength; however, the strength-first group significantly increased lower-extremity strength as compared to the endurance-first group. While the researchers found improvements in neuromuscular economy as measured by EMG of the rectus femoris in the strength-first group, other muscles of the quadriceps complex increased in this aspect in both groups. While there may be some advantages to performing strength exercises prior to endurance exercises in older adults, physical therapists may wish to design programs based on older adults' preferences or abilities, particularly if performing strength exercises first reduces the ability of older adults to perform endurance exercises. Combining strength exercises aimed at improving endurance and power exercises also improves strength and power parameters in older adults, with no apparent order effect.[271]

Physical therapists may also seek evidence for the number of days per week concurrent training should occur. One study found that twice-weekly concurrent intra-session, high-intensity strength and endurance exercise was as effective as the same intervention three times weekly in improving neuromuscular efficiency, strength, muscle thickness, peak oxygen uptake and ventilatory threshold.[272] However, larger gains can be found in a shorter period of time with three concurrent aerobic and strength training intra-sessions.[273]

Frailty and FITT Principles

The majority of older adults experience relative health on the aging continuum. However, there are extremes of this continuum. At one end of the aging spectrum are frail older adults, who are less healthy than the majority of their aging peers.

"Frailty" has multiple definitions, all of which describe a process in which multiple organ systems deteriorate. The frailty phenotype described by Fried et al is a syndrome in which three or more of the following criteria are present: unintentional weight loss of greater than ten pounds in a year, self-reported exhaustion, weakness, decreased walking speed, and decreased physical activity.[274] Individuals are classified as prefrail with the presence of one or two of these characteristics.[274] Other definitions of frailty include elements such as cognitive decline,[275] depression,[275] sarcopenia,[275,276] osteopenia,[275,276] activation on inflammatory and coagulatory systems,[275] activation of catabolic cytokines,[275] neuroendocrine dysregulation,[276] and immune dysfunction.[276] The deterioration of multiple organ systems is both a cause of and a result from physical inactivity, with a primary impact occurring in the musculoskeletal system.[277]

Frailty impacts upon functional ability, as the decline in multiple domains results in disability.[278,279] The ability to remain independent in tasks such as self-care is related to frailty: older adults exhibiting frailty are less likely to remain independent in activities of daily living and instrumental activities of daily living.[280] They are also more likely to experience periods of protracted disability after an illness.[280] This is particularly challenging with respect to common illness. Frailty is associated with poorer antibody response to the flu vaccine, placing older adults at risk for disability related to influenza.[281] Frailty-related slowness impacts the physical function domain and the associated exhaustion impacts the mental domain of health-related quality of life as measured by the SF-36.[282,283] Older adults with frailty perform more poorly on cognitive tests such as the Mini-Mental State Exam.[284,285] Low physical activity, one of the characteristics included in the frailty phenotype, also predicts future frailty as do chronic disease, allostatic load, depression, cognitive impairment and poor social support.[286]

Frailty predicts falls; loss of independence; emergency room visits and hospitalizations; assisted living unit and skilled nursing facility admissions; and mortality.[274,287] Fall risk may be related to both decreased muscle strength as well as changes in gait parameters. Older adults transitioning to a frail state have increased stride length variability.[288] Increased stance-time variability is also associated with future mobility disability. In older adults who are community ambulators, and thus are likely not exhibiting frailty characteristics, temporal-spatial gait characteristics may be different in fallers versus non-fallers. Brach et al found increased step width variability in fallers who walked at community-ambulation speeds.[289] Increased stance- and step-time variability has also been reported in early post-menopausal women with low BMD, a population at risk for future frailty.[290] These subtle changes in physical performance may yield preclinical disability or may be indicative of pre-frailty. Thus physical therapists should be concerned with both detecting those in pre-frail states as well as those exhibiting pre-clinical disability.

Preclinical disability is associated with frailty. Preclinical disability manifests as an increase in time needed to complete a task, modification of a task, or decreased frequency in task performance.[291] In community-dwelling older adults frailty may be asymptomatic due to these compensatory strategies;[279] people who engage in compensatory strategies for physical tasks such as walking a half mile have greater odds of reporting difficulty with these tasks in the future.[292] Early detection of subtle changes in physical functioning is vital to the prevention of frailty.[292] Identification of those in a pre-frail state may allow for interventions to improve health outcomes.[293] Screening with the SPPB or gait speed could help to detect frailty and provide physical therapists with a starting point for interventions, as physical activity prevents frailty.[294]

Approximately 10% of older adults age 65-75, and 50% of those age 80 and older, exhibit frailty.[281,295,296] One cross-sectional study in the Netherlands of 8,684 people aged 65 and older found that 63.2% of the population could be classified as non-frail, 28.1% as pre-frail, and 8.7% as frail according to the frailty phenotype.[297] This study found that factors associated with frailty were being female, being older, being unmarried or living alone, and having a lower education level.[297] Similar findings in the United Kingdom have been reported.[295] Physical therapists working with older adults should expect that a percentage of their caseload will include those with physical frailty.

Rantanen et al have described spiraling decline in older people.[298] Pathology leads to decreased muscle strength, which leads to difficulties in activities of daily living. Muscle strength mediates both physical activity and disability. Disability is associated with physical inactivity and physical activity is correlated with lower extremity muscle strength and disability. Because elements of the frailty phenotype include slow walking speed, muscle weakness, and low physical activity, physical therapists can use properly-dosed exercise interventions to address pre-frail and frail individuals.[299] Addressing physical activity through exercise interventions can reduce frailty risk as well as improve physical performance due to the bidirectional relationship between physical activity and frailty.[300] High intensity exercise interventions are effective in improving physical performance and functioning in older adults with mobility or physical disability and in those older adults with multiple co-morbidities.[301] The results of one recent meta-analysis demonstrate that exercise is effective to improve habitual and fast gait speed as well as scores on the SPPB in frail older adults.[302] Because regular exercise impacts multiple systems, it is an effective modality to target frailty.[303]

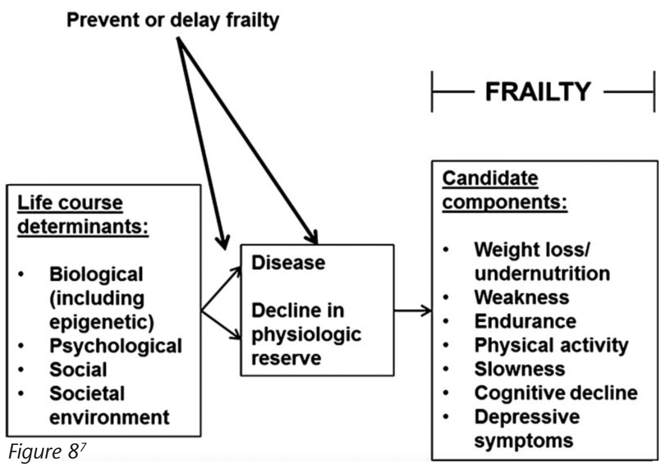

Figure 8[7]

Exercise Prescription for Frail Older Adults

Given the ACSM guidelines on exercise for older adults as well as the evidence for resistance training and multi-component exercise training, it is unsurprising that the majority of evidence for effective dosing focuses on these modes of exercise for frail older adults. For example, one study found that three months of daily high intensity exercise reduced frailty by 18%.[304] Resistance training is safe and effective for older adults with markers for frailty and has been proposed as one way to prevent frailty syndrome.[305] One study found that the oldest frail adults increased lower extremity strength by 220% after 10 weeks of a progressive-resistance program dosed at 80% of 1RM.[306] Resistance training can include high-intensity, progressive-resistance exercises and/or power training with this population.

Older adults with type 2 diabetes are one population of adults at risk for frailty. A systematic review found that high-intensity resistance training improves muscle strength and muscle power in older patients with diabetes.[307] One recent study compared healthy controls to older adults with diabetes or pre-diabetes. Participants in the exercise program engaged in a resistance-training program that was held three times a week for 12 weeks.[308] Resistance training engaged all major muscle groups and was performed in three sets of six to eight repetitions at 75-80% of 1RM. Those in the exercise group had significant increases in muscle strength, timed-up-and-go time, and 6MWT distance; the differences were not significant between healthy older adults, those with pre-diabetes, and those with diabetes.

One study examined the safety and efficacy of high-intensity resistance training in older women with low BMD.[309] Participants were randomized to an 8-month period of twice-weekly 30-minute sessions of supervised high-intensity progressive-resistance training and weight-loaded activity or an unsupervised low-intensity training control group. The participants were provided with several weeks of training in proper lifting form and safety. Participants then performed deadlift, squat, and overhead press at five sets of five repetitions at 80-85% of 1RM, in addition to the weight-loaded activity,a jumping chin up and drop down at five sets of five repetitions. The high-intensity group experienced increases in femoral neck and lumbar spine BMD and increases in lean body mass as compared to declines in the control group. Physical performance also improved as evidenced by significant increases in back extensor strength and decreased timed-up-and-go time. No adverse events were noted for the high-intensity training program, despite the deficits in participants' BMD. Physical therapists should feel confident that high-intensity resistance training is safe for older adults with low BMD as long as they are provided proper instruction in form and safety and initial supervision.

Older adults who are hospitalized are at increased risk for disability.[310,311] Proper exercise dosing for older adults who are hospitalized is imperative to counteract strength losses from prolonged hospitalization and prevent resultant functional decline and disability. One recent study examined the impact of a high-intensity, multicomponent exercise program in older adults with multiple co-morbidities as compared to usual care in a home care physical therapy setting.[312] Both groups were seen 2-3 times a week for 30 days with a 30-day discharge home exercise program provided. The multicomponent exercise program addressed transfers and ADLs, gait training, and endurance training that was progressed to 20 minutes of walking total. Additionally, upper and lower extremity strength training was performed using 8RM as the guide. Exercises were progressed from two sets of 8 to three sets of 8 using a portable resistance exercise device. The usual care group received gait training, in-home functional mobility training such as transfers, low-intensity resistance training, and a low-intensity home program. At the end of the study the multi-component group performed significantly better in gait speed, the Physical Performance Test, and the SPPB, and had no adverse events requiring hospitalization. Similar protocols for acutely hospitalized older adults have been published with an aim to prevent functional and cognitive impairment.[313]

Critically ill older adults may be frail or prefrail and can safely engage in eccentric resistance training. For example, eccentric training has demonstrated advantages over concentric training in individuals with heart failure. In one study, middle-aged and older adults were randomized to either a concentric training program on an electronically braked ergometer at 60 revolutions per minute for 25-minutes three times a week[314] or an eccentric protocol that involved the participants resisting the concentric movement of the ergometer at 15 revolutions per minute for the same duration and number of weekly sessions. Both groups had similar increases in the 6MWT, in peak work rate and in tolerance of the programs. The concentric group did experience greater improvements in aerobic capacity measures, but had decreased tolerance to the higher heart rate demands. Thus, the lower metabolic cost of eccentric training is an advantage for critically ill older adults who have reduced energy and limited functional reserves.

Older adults residing in nursing homes can also benefit from high-quality resistance training. In one pre-test, post-test design 10 older adults completed a twice-weekly resistance training program over eight weeks.[315] The older adults worked all major muscle groups using resistance machines at three sets of eight repetitions, dosed at 8RM. Resistance was progressed as 8RM increased. At the end of the intervention, significant improvements on the Elderly Mobility Scale and muscle strength were noted. No significant changes on the SF-36 were found, although it is possible with a longer training period changes in quality of life would be noted. No adverse events related to the training were reported.

Older adults with pre-frailty can also experience positive changes with resistance training of the lower extremities. One study examined the impact of a three times a week resistance training program dosed at 70% of 1RM. Muscular power of the lower extremities significantly increased and timed-up-and-go time significantly decreased.[316] Another yearlong intervention study targeting sarcopenia in patients post-hip fracture included non-exercise components such as nutrition, vitamin d supplementation, depression and cognition as compared to a usual-care control group.[317] The exercise intervention was a high-intensity progressive-resistive, strength-training program for the upper and lower extremities. The exercises were supervised and performed at 80% of 1RM. Mortality risk was reduced 81% and nursing home admission 84% as compared to the control group. The use of assistive devices and decline in activities of daily living was significantly lower as compared to the control group. No adverse events were associated with this study. This research demonstrates that high-intensity resistance training prescription is an important component of care after hip fracture and has a place amid pharmacological and psychological interventions.

Power training is feasible and equally important in frail older adults as it is for their healthy peers. Decreased muscle power is associated with increased variability in gait in frail older adults,[318] which could lead to falls and fractures as well as to decreased walking behavior. Addressing muscle power therefore could improve gait characteristics of frail older adults. Additionally, research indicates that muscle power is associated with the onset of functional decline in older women.[319] Power training therefore may work to limit the impact of or reverse frailty in older adults. However, power training may be challenging for older adults with frailty as evidence demonstrates that there is variability in the speed at which frail older adults perform power training.[320] This may require a physical therapist to supervise power-training sessions. Physical therapists may hesitate in proper dosing of power training with frail older adults; however, the Borg RPE scale is effective to estimate proper dosing.[321]

Cadore et al randomized frail older adults with a mean age of 91.9 to a control group or a twice-weekly training program of gait, balance, and power training.[322] The training took place over 12 weeks. The power-training program was performed at 8-10 repetitions of 40-60% of 1RM. The power-training group had significant improvements on the timed-up-and-go test and the timed-up-and-go dual task test. Physical performance, as measured by chair rise and balance, were significantly improved and falls were significantly decreased. Muscle strength and power were significantly increased. While balance and gait were included in this trial, physical therapists may conclude that given the growing body of evidence favoring high-intensity training over usual care the changes were likely due to power training.

Zech et al examined the impact of strength training versus power training as compared to a control group in pre-frail older adults aged 65-94.[323] All participants engaged in balance training and vitamin D supplementation. Both the strength and power group performed exercises twice a week on non-consecutive days for 12 weeks; both interventions emphasized major muscle groups. The power training group performed the concentric movements as quickly as possible and the eccentric motion over two to three seconds; the strength training group did the same exercises with both the concentric and eccentric contraction lasting two to three seconds in duration. Both groups had their resistance progressed from 10-12 on the Borg RPE scale to 16 by the end of the study; all exercises were performed with 15 repetitions. Only two of 69 total participants dropped out due to exacerbation of illness from the power training protocol; these were due to exacerbation of osteoarthritis and vertigo. Both the strength and power groups experienced improvement in SPPB score at the completion of the exercise program with no significant difference between the groups. However, the power-training group sustained these differences at the nine-month mark, whereas the strength training and experienced declines in their SPPB scores. This study illustrates that the gains from power training may be more beneficial in the long term as compared to strength training. Additionally, power training appears to be well tolerated by pre-frail older adults.

One high-intensity aerobic training intervention enrolled pre-frail and frail older adults living in an assisted living facility in 12-weeks of supervised training.[324] Aerobic training consisted of 30 minutes of high-intensity walking at 15-17 on the Borg RPE. The training included fast walking, stair climbing, and uneven surfaces. Frailty was reduced and fast walking speed, 6MWT, and Berg balance scores were significantly increased.

Exercise that includes both high-intensity resistance training and HIIT aerobic training has been explored as an effective intervention for older adults. A 2013 systematic review suggests that a combination of strength, aerobic, and balance training is the most effective method to reduce falls, and improve balance, gait, and strength in frail older adults.[325] A second systematic review performed in 2017 examined 5000 articles and included 12 studies to look at single- versus multi-component exercise impact on frailty.[326] The studies included eight with a nutritional component and an exercise component and one with hormonal supplementation and exercise. The final three studies each included nutrition and exercise with one additional component: one included psychotherapy, one included hormonal supplementation, and one included cognitive interventions. Eleven studies included strength training; three studies had only strength training and the others had strength in combination with elements of balance and/or aerobic training. The majority of included studies reported high-intensity training of an appropriate dosage. Significant improvements were reported by various included studies in frailty status or score, muscle mass, muscle strength, gait speed, physical activity, and physical functioning as measured by the SPPB. Overall, the authors of the systematic review conclude that multi-component interventions are more effective than single-component interventions at improving frailty characteristics and functional mobility. Physical therapists, being mindful of the ACSM guidelines for exercise prescription, should consider strength and aerobic training in combination to address frailty. This systematic review included studies with a wide variety of intervention methodologies. Physical therapists should include interventions that address their specific clients' deficits, including balance, and should refer out to registered dieticians, endocrinologists, and family physicians if interventions outside of their scope of practice are deemed necessary.

One study that included both adults in middle age and older adulthood with heart failure randomized participants to either a high-quality exercise program or a usual-care control group where no information was provided about exercise.[327] The aerobic training component was performed on a cycle ergometer at a cadence of 50 to 60 rpm with a peak work rate of

100% for 30 seconds alternating with 30 seconds of rest. Aerobic sessions were 45 minutes long. Resistance training worked major muscle groups for three sets of eight repetitions and was progressed from 30% of 1RM to 90% of 1RM by the end of the training program. The intervention took place three days a week for 12 weeks. In addition to aortic dilation and systolic blood pressure, the exercise group had significant improvements in 6MWT distance, VO_{2max}, and greater peak power. No adverse events occurred as a result of the exercise training.

Another study examining multi-component exercise included nine moderately frail, older adults age 65-80 with obesity.[328] The exercise program was 90 minutes, three days a week for 12 weeks and was supervised by a physical therapist. The sessions included 15 minutes of flexibility exercise. This was followed by 30 minutes of aerobic activity on equipment such as a treadmill, stationary bike, or stairmaster, or stair climbing/step up activities at 75-80% of peak heart rate. Resistance training worked major muscle groups and was progressed from 65% of 1RM with one to two sets of 12 repetitions to 80% of 1RM with two to three sets of six to eight repetitions. Significant changes in body composition were noted, with fat mass decreasing and lean body mass increasing. Upper and lower body strength significantly increased, as did gait speed, one-legged standing time, and aerobic capacity. Chair rise time significantly decreased.

One yearlong study examined the impact of multi-component exercise as compared to a standard-care control group.[329] The exercise training took place at various community centers. Training included balance and functional exercises, weight-bearing impact exercises, and rapid concentric strength training to address strength and power. The strength and power exercises were progressed using the modified Borg RPE scale, beginning at a 3-4 rating and progressing to a 5-8 rating. The program had 40 injuries or complaints by 34 of 81 total participants. About half of these were exacerbations of pre-existing injuries, 27 injuries required treatment, and six participants withdrew from the study as a result of their injuries. The other injured participants had the exercises modified so that their continued participant was possible. Strength, power and bone mineral density significantly improved in the exercise group. This study demonstrates the effectiveness of intensive exercise programming, but serves as a reminder to physical therapists that frail older adults may require modification of exercises and monitoring of response to high-intensity training to prevent injuries.

Another high-intensity training program randomized sedentary, frail older adults to a high-intensity, multi-component exercise program or a control group that attended a regular primary care program.[330] The exercise program included a 10-minute warmup, 10-15 minutes of balance and proprioceptive training, 40 minutes of aerobic training with two of those sessions including strength training, and five minutes of stretching. Strength training utilized resistance bands and was progressed from 25% of 1RM to 75% of 1RM. Aerobic training was progressed from 40% to 65% of maximum heart rate. The exercise group significantly increased energy expenditure by increasing weekly physical activity and significantly reduced primary care physician visits. Physical functioning as measured by the physical performance test and the SPPB were significantly improved. Frailty characteristics were significantly reduced and 31.4% of those in the exercise group had their frailty reversed; the relative risk of frailty reversal was 2.4. Ability to perform activities and instrumental activities of daily living significantly improved, as did scores on the mini-mental state exam. This study clearly demonstrates the ability of high-quality exercise intervention to improve physical functioning impacted by frailty, as well as the ability of effectively dosed exercise programs to reverse frailty.

The LIFE study included sedentary older adults ages 70-89 that were determined to be at risk for mobility disability in an intervention versus a health education control group.[331] The intervention was multi-component and consisted of flexibility, aerobic training for 150 min/week at 13 on the Borg RPE scale, and lower extremity strengthening exercises performed with ankle weights at 15-16 on the Borg RPE scale. The first 24 weeks consisted of two to three days per week of supervised exercise, and then weeks 25 to 52 were performed at home with the option to come into the training center once or twice a week. Monthly phone calls occurred during the home program phase. At the end of the 12 months, prevalence of frailty had significantly decreased in the intervention group. The number of frailty criteria present also significantly decreased at 12-month follow-up, with sedentary behavior the frailty criteria most impacted by the physical activity intervention.

Another multi-component program consisted of frail and pre-frail older adults randomized to interventions focused on exercise, nutrition, cognitive training, or combination of all three.[332] Physical activity occurred twice a week for 12 weeks, with sessions being 90 minutes duration. Progressive resistive exercise was one set of at 60-50% of 10RM of all major muscle groups. Functional tasks and balance exercises were also part of this program. The nutrition intervention increased caloric intake by 20% with a vitamin-rich formula. Cognitive training worked on short-term memory, problem solving, attention, and processing. Of 246 participants, only two adverse events of joint pain occurred. Over 12 months, the combination intervention had an odds ratio of 5 for reducing frailty, with physical activity having an odds ratio of 4.0 for decreasing frailty. The nutrition-only and cognition-only groups had a 3 times greater odds for decreasing frailty as compared to the control. The physical intervention had increased gains in knee strength, energy, and physical activity. The nutrition group was the only group that had significant increases in physical activity. The cognition and combination groups also exhibited increases in knee strength. This study demonstrates that combination and physical activity interventions are successful in reducing frailty.

The evidence demonstrates that multimodal exercise increases physical capacity in older adults.[333] Because frailty is associated with sedentary behavior, physical therapists should focus on exercise as an effective frailty treatment.[334] Frailty interventions aimed at preventing comorbidities, disability in instrumental activities of daily living, and increasing physical activity should be paramount.[335] Effective exercise dosing is the intervention that will address all of these areas.

Senior Athletes and FITT Principles

At the other end of the aging spectrum are senior athletes. Senior athletes represent the most successful agers. One qualitative study examined the impact of competing in the Senior Games to determine how participation impacted upon successful aging.[336] Five themes emerged from open-ended interview questions. The first theme was perseverance, which included pushing through injury as well as surviving serious illnesses. The second theme was the serious effort required of continued sports participation. The third theme was personal and social benefits, with participants noting having good health, enhanced self-image, and networking with friends as a result of sports participation. The fourth was a unique ethos in which sports participation shaped friendships, caused participants to connect with each other outside of competition, and even train together. The final theme was identification as a senior athlete, with older adults developing a strong self-concept surrounding their participation in their sport. These themes highlight both the psychosocial support older adults gain through sports participation as well as the strong self-concept achieved through identification as an athlete. Physical therapists should be mindful that senior athletes achieve benefits beyond physical health, and thus training regimens should be aimed at keeping older adults active in their chosen sport.

We can think of senior athletes in terms of three broad categories: former competitive athletes, lifelong athletes, and non-athletes who came to exercise late in life.

Former competitive athletes may or may not be competing in their sport.[337] Those who are still competing may have reduced their training intensity, but may be enjoying their sport at a recreational level.[337] Others may have sustained an injury that prevents them from competing in their initial chosen sport.[337] All former competitive athletes in this category engage in regular physical activity and continue to exercise recreationally.[337] Older adults who are former competitive athletes experience higher self-rated health as compared to healthy community controls.[338] One study examined 514 senior athletes who had competed for Finland compared to 368 who were healthy at age 20. Among former athletes, 64% rated their health better as compared to 48% of controls. 54% of athletes and 44% of peers were the most physically active; 59% of athletes never smoked as compared to 37% of peers. Athletes had significantly higher self-rated health after controlling for age, physical activity level, alcohol and tobacco use, and occupation.

Lifelong athletes exhibit a wide variety of sports and training levels.[337] The hallmark of a lifelong athlete is involvement in a specific sport or sport.[337] Lifelong athletes may be either senior athletes who are involved with an organized team or an individual sport that requires regular competition.[337] These senior athletes will be achievement oriented and focused in their training. Some athletes in this category are elite senior athletes who are at greater risk of overuse injuries.[337] Just as their younger athletic peers, lifelong senior athletes may ignore pain or injury in an attempt to continue participating in their sport.

Some non-athletes come to exercise late in life.[337] They may begin sports participation due to a health issue.[337] These older adults may either participate in their sport competitively or recreationally.

Whatever the category, senior athletes differ from their younger athletic peers due to age-related physical changes. When we consider the biological changes at the level of muscle, tendon, ligament, and bone, senior athletes have decreased flexibility, lower muscle mass, lower aerobic capacities, and a compromised thermoregulatory system. Just as we should not consider all older adults as frail, physical therapists should also not treat senior athletes identically to their younger, athletic patient caseload. Physical therapists should consider overuse, overload, and overstretch with older athletes in the context of both training and aging.[337]

Like their younger counterparts, senior athletes can experience injuries that are acute and/or traumatic, or from overuse. Unlike younger athletes, however, these injuries need to be considered in conjunction with musculoskeletal changes associated with aging.[337] Due to reduced bone density and increased ligamentous stiffness, older adults might be more likely to sustain a fracture versus a sprain or avulse a tendon rather than strain a muscle.[337] Senior athletes may be acutely aware of the impact of rapid detraining on their athletic careers and may attempt to minimize these injuries or return to their sport more quickly than is advisable. Likewise, all athletes are susceptible to overuse injuries due to training regimens,[339] including muscle strains, tendinitis, bursitis, and stress fractures;[337] however, older adults may be more prone to these types of injuries due to the increasing stiffness of collagen, which results in reduced flexibility.[340,341] Reduced muscle mass results in decreased shock absorption through the joints, which can also create a situation in which an overuse injury is sustained.[342,343] Finally, altered movement patterns from muscle stiffness, prior injuries, and arthritic changes may result in an overuse injury.[344] Prevention of injuries should be the focus of any exercise prescription for this population, and should include high-intensity resistance training to increase strength and muscle size, counter sarcopenia, and thus prevent injuries.

Unlike sedentary older adults, senior athletes are accustomed to delayed onset muscle soreness (DOMS), which is common when a new exercise program or activity is initiated.[337] The incidence of DOMS is similar to that of younger athletic populations;[337] eccentric activity is more likely than concentric activity to result in DOMS.[342] Senior athletes accustomed to DOMS and pushing through pain may ignore pain that signifies something more serious; thus, senior athletes should be provided education that pain lasting longer than 48 hours may be the result of injury rather than training. One way to help reduce injury risk is to initiate cross training, rather than performing less intense workouts for the sport between harder workouts. Training intensity can also be looked as a potential cause of injury. Training intensity will be discussed in greater detail later on in this section.

Although lifelong athletic participation places senior athletes at greater risk for osteoarthritis,[345] it is important to look beyond arthritis as the cause of pain. In the senior athlete, it can be attributed to a specific event, a change in training routine or volume of activity, or structural abnormalities in the joint. At the same time, it is also important to not treat senior athletes as fragile or more likely to be injured. One analysis related to the Runners' Health Study looked at impact of running and other aerobic exercise on musculoskeletal pain at a 14-year follow-up period.[346] Participants included in the analysis were 492 runners and 372 community controls. Participants were mailed health assessment questionnaires; were asked about physical activity; and were given a 0-100 visual analog pain scale. As compared to the control group, runners were younger, had lower baseline levels of pain, lower BMI, less likely to smoke, and exercised more minutes. Visual analog pain scores were 25% lower in runners than in non-runners/community controls. While pain increased with age for both groups, it increased to a lesser extent for runners. Physical therapists thus can feel confident that older athletes will not experience a great deal of pain.

Participation in athletics has a positive impact on the psychosocial health of older adults.[336] Lifelong training can reduce oxidative stress and muscle damage and improve antioxidant response.[347] One 21-year follow up in the Runners Health Study compared 284 runners to 156 controls.[348] Runners had a lower baseline level of disability, less disability at follow up, took 6 years longer to become disabled, and were less likely to experience early mortality. Even runners who stopped running had lower disability, suggesting that former competitive athletes who decrease their training or switch sports may still experience lower levels of disability than their healthy peers.

Additionally, intensive training has important impacts on bone, muscle, and the cardiovascular system.

Intensive training may work to counteract age-related losses in BMD. While senior athletes are not immune to age-related losses in BMD,[349,350] physical activity does work to counteract BMD losses that go unchecked in sedentary older adults.[37,351] And while senior athletes' BMD profiles become more similar to sedentary peers with advancing age, BMD and BMC in post-menopausal women who were elite athletes in their youth are higher than nonexercisers,[352] which suggests that lifelong and former competitive athletes have an advantage with respect to BMD for much of their lifespan over sedentary peers and those who come to athletics later in life.

Competitive athletes in the Senior Games exhibit 38% greater knee extension strength and 66% greater knee flexion strength than sedentary, age-matched controls.[353] Senior athletes demonstrate faster performance on the five times sit to stand test.[354] Vigorous athletes perform better than recreational athletes, but all perform better than age-related norms.[354] Maximal voluntary contraction and electromyographic activity are similar in older and younger endurance athletes,[355] suggesting that functional ability is preserved in older athletes despite sarcopenic changes.

While the rate of cardiovascular events due to extreme exertion increases in the senior athlete,[339] the majority of senior athletes are at an advantage with their cardiovascular system. Their increased ability to maximize oxygen consumption actually places them at a decreased risk for dependence and mortality.[356]

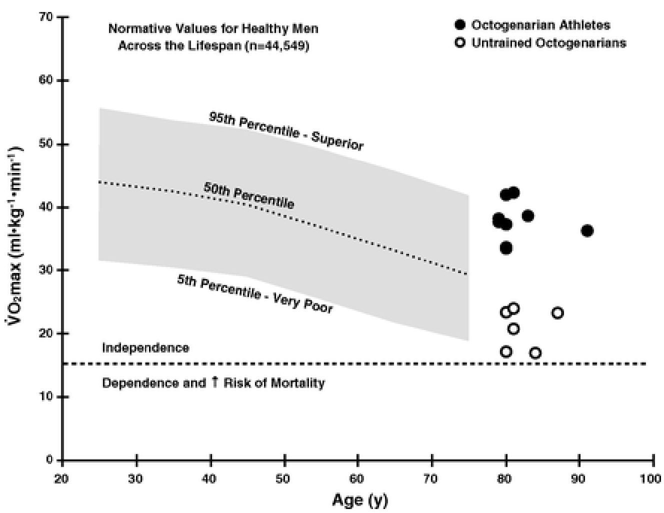

Figure 9[8]: Individual V_{o2max} data from the octogenarian lifelong endurance athletes and healthy untrained octogenarians. The dotted line represents the prognostic exercise capacity [5 metabolic equivalents (METs), 17.5 ml·kg−1·min−1] generally necessary for an independent lifestyle and associated with an increased risk for mortality as described by Meyers et al. (41). The normative values for healthy men across the life span (n = 44,549) were originally obtained from the Cooper Institute in Dallas, TX, and have been summarized by the American College of Sports Medicine (1).

This cohort has demonstrably better oxygen utilization as well as significantly better capacity to perform aerobic and anaerobic exercise as compared to healthy peers.[357] Bouvier et al examined the impact of lifelong intensive training in athletes 70 and older on cardiovascular capacity, left ventricular function, and perfusion.[358] VO_{2max}, peak workload, systolic and diastolic left ventricular function, and increased left posterior ventricular wall thickness were significantly increased in lifelong athletes as compared to healthy controls. While both groups had similar ejection fractions at rest, athletes had higher ejection fractions with exercise. Additionally, seven of the ten athletes had perfusion defects that were primarily localized to the posterior or postero-lateral ventricular wall that were exhibited either at rest or with exercise. However, the authors caution that perfusion defects are common in both younger and older athletes and may suggest differences in the distribution of myocardial blood flow compared to sedentary individuals. VO_{2max} in older athletes is higher than in sedentary young controls.[359] Both younger and older athletes have similar declines in VO_{2max} with detraining, and both exhibit higher VO_{2max} values after detraining as compared to their sedentary peers.[359] Additionally, both younger and older athletes exhibited similar increases in left ventricular wall thicknesses, end-diastolic diameter and volume, and left ventricular mass.[359]

Senior athletes are at lower risk for chronic disease than their peers,[360] but are at greater risk for training-related injuries. Thus, when considering the senior athlete, injury prevention may be the most important area of focus for exercise dosing. One recent Cochrane review examined injury prevention strategies in athletes.[361] Preventative strategies with respect to training programs were used in 45% of the 155 studies included. Pre-event training was included as a prevention strategy in 58 studies, with 58% of these studies focused on strength training, 45% on balance and coordination training, 31% on flexibility and 30% on plyometrics. This underscores the necessity for a comprehensive program for senior athletes.

Exercise Prescription for Senior Athletes

Decline in performance with aging may contribute to overtraining injuries. One study found that senior track and field athletes' performance declined in both males and females approximately 3.4% per year over 35 years of competition.[362] This decline began slowly from age 50-75 and increased dramatically after age 75. Men had no decline difference between sprint and endurance events; women had greater declines in sprint events particularly after age 75.[363] Performance in running was consistent through age 35; performance declined slightly through ages 50-60 and then sharply declined through age 70. Women experienced a three times greater decline in performance as compared to men. Swimming yielded sharper declines later in the lifespan, with significant decline in performance at age 70. Women and men had smaller differences between their performance declines. Age-related declines in VO_{2max} and lactate threshold may be the primary reason for reduced performance. Even in the marathon, which favors the ability to generate a sustained effort over pure speed, times increase with each age group from age 70 onward.[364] Interestingly, in the extreme endurance sport of ultra-running, the youngest age cohort of 18-24 slowed down significantly from the first segment of the race, whereas the oldest runners did not slow down.[365] Older adults may be more attuned to even pacing, which can yield high- and low-intensity workouts performed at a correct and consistent pace.

One way to counteract the concerns about age-related declines in performance would be through the use of age-graded performance tables for individual endurance sports. Age-grade tables allow for a conversion of times per age to younger times. Age grading exists for swimming (http://www.usms.org/articles/articledisplay.php?aid=143), cycling (http://www.owensoundcycling.ca/agegrading.html), and running (http://www.runnersworld.com/tools/age-graded-calculator). Age-graded times allow for realistic goal setting and comparison to older and younger athletes' times.

Another injury-prevention strategy for senior athletes may be active-rest periods and within-session monitoring of RPE. One study in younger runners found that increased RPE in workouts was correlated with decreased strength and power, as well as slower times in the 50-metre sprint. Having athletes participate in a month of active rest ensured preservation of strength and power.[366] Therapists can also introduce cross training to allow for active recovery blocks within a yearlong training cycle. This will help preserve strength and power in their clients.

Physical therapists can teach older adults to train at lower intensities through using the Borg RPE, or through the use of a heart rate monitor so that non-HIIT workouts are performed at the correct intensity of 55-85% of maximum heart rate or 12-16 on the Borg RPE scale.[367] Another way to monitor intensity is through the talk test, in which an athlete can still carry on a conversation comfortably:[367] the ability to comfortably carry on a conversation during exercise correlates with moderate intensity.[368] In exercise testing, the last stage at which a person can speak comfortably is typically just below the ventilatory threshold;[368,369] the first stage when a person can't decide if they can speak comfortably correlates with the ventilatory threshold;[368,370,371] and the first stage at which a person says they can't speak comfortably correlates with the respiratory compensation threshold.[368,370,371] Research demonstrates that the talk test can help individuals stay in the moderate-intensity range as measured by the Borg RPE scale. The talk test or the Borg RPE scale would be necessary to use with older adults on beta blockers, who would be unable to use heart rate as a guide for exercise intensity.

The evidence for high-intensity interval training and progressive resistance training in healthy, older adults can be applied to senior athletes. A combination of strength/power and aerobic training will yield positive training results in this population. For example, power-trained Masters athletes, a class of athletes which includes a senior athlete population, exhibit significantly higher muscle mass and mother units as compared to community-dwelling peers.[372] Former elite power trained athletes exhibit greater explosive force than other former elite athletes and controls.[373]

Unhjem et al examined the role of long-term strength training in three groups of older males: strength-trained Masters athletes, recreationally active older adults, and sedentary older males.[374] These three groups were compared to moderately active older adults. Masters athletes had significantly higher leg press 1RM as compared to the other three groups, with younger moderately actively older adults having higher 1RM as compared to recreationally active and sedentary older adults. Masters athletes and young adults had similar rate of force development profiles and chair rise times, with both having significantly higher rate of force development as compared to recreationally active and sedentary older adults. Young adults had significantly higher stair-climbing power as compared to all other groups, with Masters athletes having significantly higher power than the other two older adult groups. The walking speeds of Masters athletes, recreationally active older adults, and young moderately active older adults were similar; all were significantly higher than sedentary older adults. This article provides strong evidence for the benefits of long-term strength training for older athletes. Plyometric training may be one method of increasing strength and power in senior athletes. Older athletes and younger populations equally tolerate plyometric training.[375]

Senior athletes may be concerned that strength training may limit aerobic conditioning, but the evidence finds no change in cardiovascular endurance in older adults who engage in regular strength training.[376] Additionally, research indicates that college-aged and older adult women exhibit similar profiles for muscle damage and repair in eccentric-training exercises.[377] Given that senior athlete data is still emerging and highly trained older adults have similar profiles to younger adults, examining data from younger cohorts can be useful. Mikkola et al examined a cohort of younger cross-country skiers in which the control group continued their typical endurance training regime and the intervention group replaced 27% of their endurance training with explosive strength training of the lower extremities.[378] The intervention period was eight weeks in duration. Despite the reduction in the amount of endurance training, VO_{2max} was preserved. Additionally, the explosive-training group experienced significant improvement in explosive force production and greater economy in cross-country skiing performance. Concurrent endurance and high-intensity strength or power training has been shown to significantly increase the velocity of maximal oxygen uptake, strength, and neuromuscular performance.[379] Senior athletes new to resistance training should feel confident that resistance training does not lead to injury. On the contrary, including progressive, high-intensity strength training is instrumental for injury prevention in older athletic populations.

Evidence suggests that in younger endurance athletes, high-intensity resistance training, power training, or a combination of both modalities in combination with aerobic training yields increases in strength, power, and endurance.[380] Physical therapists should encourage their senior athlete clientele to do a combination of strength and power training.

HIIT yields similar results across age groups ranging from 20 to 70 and older.[381] All age groups demonstrate significant increases in VO_{2max}, with no significant between group differences.[381] Additionally, older adults exhibit a tendency towards an increase in maximum heart rate.[381] Evidence suggests that higher VO_{2max} in older athletes is due to increased plasma and total blood volume in these individuals.[382] However, we may need to consider the volume of HIIT training compared to low-intensity training for senior endurance athletes. Evidence on elite endurance athletes from a variety of sports including rowing, cycling, and running suggests that approximately 80-90% of training is at low-intensity with the remaining at intensities that range from moderate to high-intensity; however, recreational athletes appear to train at a 50/50 split of high/moderate and low-intensity training.[383-388] One study examined a combination high-volume, low-intensity training; lactate threshold training, and HIIT against each training style on its own. The combination training yielded the greatest gains in maximal aerobic capacity and peak power. Threshold training and high-volume, low intensity training did not significantly improve these variables, although they did yield minor improvements in work economy.

Physical therapists may wish to counsel their senior athlete clientele that reducing their volume of high intensity to 10-20% that includes HIIT and/or threshold training could serve them as they pursue longevity and optimum performance in their endurance sports. Studer suggests that a low-volume HIIT training program may increase aerobic capacity with shorter duration of training for this athletic population.[389] Cycling data corroborates that a 10-week HIIT program comprised of shorter intervals produced significantly larger gains in VO_{2max} than longer intervals.[390] Studer suggests that use of the Wingate test, in which athletes run for 30 seconds at maximum speed followed by two to three minutes of running at a recovery pace over 20 minutes can improve muscle oxidative capacity over the course of a few sessions.[389] Using a HIIT training session such as this, in combination with high-volume, low-intensity training, can yield efficient cardiovascular adaptations for any level of senior athlete. For example, the evidence demonstrates that while the percentage of heart rate maximum decreases as running distance increases, the percentage of heart rate maximum profile decreases similarly in runners regardless of pace.[391] This leads one to conclude that training the cardiovascular system in recreational and amateur athletes similarly to elite athletes would be appropriate.

Conclusion

While senior athletes represent the highest level of trained older adult and physical therapists would expect this population to see the largest health benefits, the benefits of proper exercise dosing are multiple for older adults across the aging spectrum and extend beyond physical functioning.

The evidence is clear in linking exercise and cognitive functioning in healthy older adults.[392,393] It facilitates neuroprotection and neuroplasticity[394] and improves cognitive function.[395] Aerobic fitness is associated with increased hippocampal volumes, thus impacting memory processing[396] and improved brain blood flow.[397,398]

Physical training triggers a number of favorable cardiovascular effects including sympathetic deactivation, increased baroreceptor activity, insulin sensitivity, and improvement in endothelial function.[399-402] Those who participate in regular exercise have a reduced risk of cardiovascular-related deaths.[403] Exercise reduces comorbidities including the incidence of dementia and several cancer types.[404-406] Regular exercise training results in increased organ reserve.[407-409]

Revisiting General Exercise Recommendations

Physical activity is a key to successful aging. Sedentary behavior and physical activity each are independently related to successful aging:[410] there is a dose-response relationship noted between sedentary behavior and successful aging, which is to say that the less time spent that is spent in sedentary behavior yields greater measures of successful aging.[410] Moreover, the greater time that is spent performing physical activity, the greater likelihood of successful aging.[410] However, meeting the ACSM recommendations for the number of weekly minutes spent in physical activity, but spending the greater majority of the time engaging in sedentary pursuits, will place a restriction on successful aging.[410] There is evidence to support that adults who engage in exercise training naturally increase their physical activity levels outside of exercise training.[411] This may be because of increased competency, functional fitness or both.

Maintaining or increasing physical activity is necessary as we age. Physical activity is associated with decline in mortality,[412] which may be due to the positive relationship between physical activity and telomere length.[413] Physical inactivity is linked with loss of muscle mass and strength due to sarcopenia.[414]

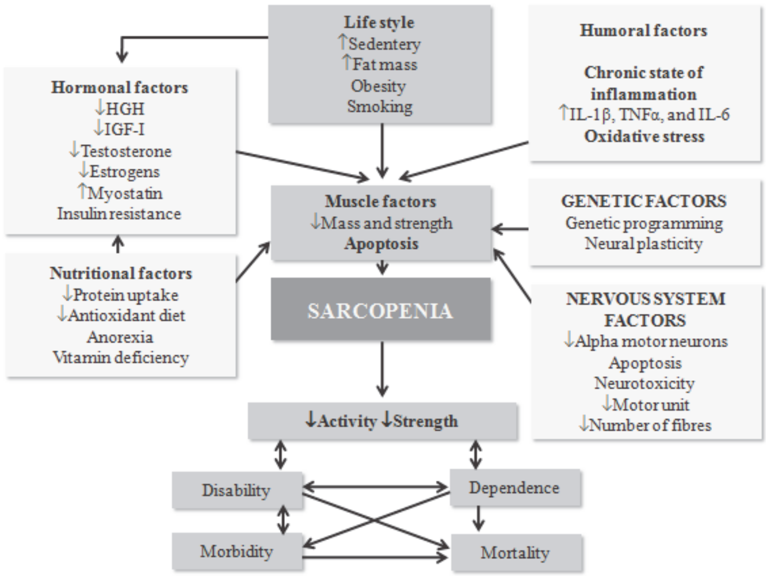

Figure 10: Scheme of the different etiological sarcopenia mechanism and their consequences [9]

A sedentary lifestyle and sarcopenia are two factors that result in functional decline with aging. Preventing loss of muscle mass and maintaining mobility are critical to the concept of successful aging.[415] There are no medications approved for the treatment of mobility loss; however, the body of evidence for exercise is positive for prevention and treatment of mobility loss.[415]

Exercise reduces blood pressure, improves aerobic capacity, and increases cardiac output.[416] Physical performance, strength, and fat free mass all increase with strength training.[414] Physical activity, particularly resistance training, has a positive association with BMD.[351,417] Aerobic training, while increasing aerobic capacity and endurance, does not impact functional mobility to the degree that strength training does.[416] Thus, a combination of aerobic, resistance and flexibility training is crucial for maintaining mobility in older adults.[418] Multi-component exercise programs that are properly dosed follow ACSM guidelines for exercise training in older adults.[109]

The safety and efficacy of multi-component programs that include both aerobic, strength and/or power training has been demonstrated in populations such as persons with osteoarthritis,[419,420] cardiovascular disease,[327,421] diabetes,[307,422] COPD,[423] depression,[424] those who are overweight or obese,[425,426] those who fall or are at risk for falls,[427-431] those with mobility disability,[427-430] those who are post stroke,[432,433] and those who are physically frail or at risk for frailty.[434]

In addition to being safe, strength training reduces mortality in older adults. [212]

Long-term strength training dosed at appropriate levels improves strength in older adults, with benefits seen for several years past the conclusion of training.[435] High-quality strength training programs should be consistent, with the most positive results being seen in older adults who train for greater than one year. A recent meta-regression suggested training at 70-79% of 1RM, with optimal benefit seen in training three times per week and two to three sets of each exercise being performed at a slow speed.[436] However, evidence in the literature suggests that this recommendation is not absolute. Training two times per week can also be beneficial and one set of each exercise and a combination of strength and explosive power training can help address function as well as athletic performance. Progressive-resistance strength training improves physical functioning and muscle performance even in older adults who reside in nursing homes, regardless of the presence of chronic diseases, chronological age, a sedentary lifestyle, or disability.[437] The inclusion of eccentric training has no demonstrated increase in muscle damage over concentric activity[438] and positively impacts measures of physical function as well as metabolic variables such as insulin sensitivity and cholesterol.[439] Power training is more effective than standard progressive resistive exercise in promoting muscle power[238,440,441] and muscle mass.[239] Because of the strong relationship between power and physical functioning,[442-444] power training is strongly recommended for inclusion in the exercise programs for older adults. High-intensity strength and power training has been found to be safe and effective on a wide range of older adults, including those who are frail and the oldest of old.[445]

In addition to the evidence for strength training in older adults, healthy and frail older adults alike tolerate aerobic training.[446] Aerobic training is proposed as an essential component to successful aging, given its ability to combat age-related changes in aerobic capacity and endurance. One study demonstrated that a progression of six, five-minute intervals with one to two minute rest periods to two, 15-minute treadmill sessions with a one to two minute rest period at a moderately hard rating on the Borg RPE scale over a period of eight weeks significantly increased gait speed and improved temporal-spatial gait parameters such as stride and double-support time in frail older adults.[447] A recent systematic review found that cycle ergometry training was effect in improving aerobic capacity, strength, body composition, and metabolic markers.[448] One meta-analysis of aerobic training in healthy older adults found an average increase of 16% in VO_{2max} across studies.[449]

Sedentary older adults will still reap benefits from physical activity: physical activity increases longevity both in active[450,451] and in previously sedentary older adults.[452,453] While any increase in activity will have a positive benefit, proper dosing of exercise and prescription of a multi-component program is critical to ensure the maximization of gains from exercise. Those who are frail or sedentary may in fact see the most dramatic gains in function with the addition of progressive resistance strength exercises.[454,455] However, physically active older adults will add to their functional reserve with the addition of strength training,[456] even if they do not see the same immediate changes in functional mobility.

Once older adults are given medical clearance to participate in exercise, physical therapists can use the results of their examination to target any impairments and functional limitations identified and to reduce or prevent disability.[416] Physical therapists should be prepared to prescribe older adults, regardless of physical activity or frailty status, with optimally dosed comprehensive exercise programs.

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EXERCISE TRAINING-BASED INTERVENTIONS FOR THE OLDER ADULT

(3 CE HOURS)

FINAL EXAM

1. **There are various areas that impact successful aging, which can be thought of as the rule of fourths. Which of the following is NOT one of these areas?**
   a. Disease
   b. Misuse
   c. Overuse
   d. Physiological aging

2. **Changes in joint structures associated with aging include ________.**
   a. Atrophy of Type I muscle fibers
   b. Decreased thickness of the left ventricular posterior wall
   c. Increased stiffness within fibrous structures
   d. None of the above

3. **Changes in muscle associated with aging include ________, a universal aging phenomenon characterized by a progressive loss of skeletal muscle fibers and fat free mass.**
   a. Alopecia
   b. Osteopenia
   c. Osteoporosis
   d. Sarcopenia

4. **Cardiovascular changes associated with aging include ________.**
   a. A decrease in the diameter of the arteries and increases in arterial wall compliance
   b. The rise of blood pressure, primarily the systolic measurement
   c. Ventricular hypotrophy
   d. All of the above

5. **Changes to the pulmonary system associated with aging include ________.**
   a. A reduction in the work of breathing
   b. Impaired gas exchange
   c. The alveolar ducts and alveolar openings contract significantly
   d. All of the above

6. **The ________ is a combination of three reliable and valid tests of balance, walking speed, and lower extremity strength. This test is easy to perform in a variety of settings, but was designed for use in community-dwelling older adults' homes.**
   a. Continuous Scale Physical Functional Performance (CS-PFP) Test
   b. Functional Fitness Test (FFT)
   c. Short Physical Performance Battery (SPPB)
   d. Six-minute walk test (6MWT)

7. **This screening tool assesses performance on tasks associated with physical function in independent older adults 60 and older: ________**
   a. Functional Fitness Test (FFT)
   b. Gait speed
   c. Short Physical Performance Battery (SPPB)
   d. Six-minute walk test (6MWT)

8. **FITT principles need to be considered when making an exercise prescription for any client: FITT stands for ________.**
   a. Frailty, intensity, time, and tempo
   b. Frailty, interval, time, and type
   c. Frequency, integrity, tempo, and type
   d. Frequency, intensity, time, and type

9. **The American College of Sports Medicine (ACSM) recommends that older adults engage in flexibility exercises ________.**
   a. Every other week; stretches should be held for 15-30 seconds
   b. On two or more days per week; stretches should occur just to the point of tightness, not pain
   c. Once per week; stretches should emphasize quick, repeated movements
   d. None of the above

10. **Regarding strength training: Ahtiainen et al performed a retrospective analysis of 10 high-quality resistance-training randomized controlled interventions, all of 20-24 weeks duration enrolling a total of 287 participants, that they had conducted. The purposes of their study were to determine if there were age- or sex-specific changes in strength and muscle size, and to determine the proportion of participants in their study who were low-responders to resistance training. Findings included: ________.**
    a. 1RM and 1RM/body mass significantly increased in all groups from pre-test to post-test, regardless of age or sex
    b. Muscle size increased significantly from pre-test to post-test, regardless of age or sex
    c. Non-, low and high responders were represented in both sex and across all age categories for muscle size gains
    d. All of the above

11. **Regarding endurance training: One study enrolled healthy, sedentary men aged 70-80 in either a control group or a group that trained on a cycle ergometer for 30-45 minutes at 50-70% of VO2max three times a week over 16 weeks, followed by a four-week detraining period. The study concluded: ________.**
    a. Like high-intensity resistance training, aerobic training does not result in persistent strength and power gains through detraining periods
    b. Like high-intensity resistance training, aerobic training results in persistent strength and power gains through detraining periods
    c. Unlike high-intensity resistance training, aerobic training does not result in persistent strength and power gains through detraining periods
    d. Unlike high-intensity resistance training, aerobic training results in persistent strength and power gains through detraining periods.

12. **Regarding multi-component exercise programs: A study compared combination resistance and endurance training, to resistance-only training, to a control group in healthy older adults. Findings included: ________.**
    a. Both training groups had significant improvements in blood pressure; the combination group also experienced significant improvements in BMI, as well as waist and abdominal circumference.
    b. Both training groups had significant improvements in BMI, waist and abdominal circumference, and blood pressure, as well as significant reductions in fat mass
    c. Both training groups had significant improvements in BMI, waist and abdominal circumference, and blood pressure; the combination group experienced significant reductions in fat mass
    d. Both training groups had significant improvements in BMI, waist and abdominal circumference, and blood pressure; the resistance-only group experienced significant reductions in fat mass

13. **Which of the following statements regarding frailty is INCORRECT?**
    a. Approximately 20% of older adults age 65-75, and 75% of those age 80 and older, exhibit frailty
    b. Frailty predicts falls, loss of independence, emergency room visits and hospitalizations, assisted living unit and skilled nursing facility admissions, and mortality
    c. Preclinical disability is associated with frailty
    d. The frailty phenotype described by Fried et al is a syndrome in which three or more of the following criteria are present: unintentional weight loss of greater than ten pounds in a year, self-reported exhaustion, weakness, decreased walking speed, and decreased physical activity

14. **Older adults with type 2 diabetes are one population of adults at risk for frailty. One recent study used an exercise program to compare healthy controls to older adults with diabetes or pre-diabetes. After 12 weeks, participants in the exercise group demonstrated ________.**
    a. Significant increases in muscle strength, timed-up-and-go time, and 6MWT distance in adults with pre-diabetes and those with diabetes; healthy older adults showed minor increases
    b. Significant increases in muscle strength, timed-up-and-go time, and 6MWT distance in healthy older adults and those with pre-diabetes; those with diabetes showed minor increases
    c. Significant increases in muscle strength, timed-up-and-go time, and 6MWT distance in healthy older adults; those with pre-diabetes showed minor increases; those with diabetes showed no increases
    d. Significant increases in muscle strength, timed-up-and-go time, and 6MWT distance; the differences were not significant between healthy older adults, those with pre-diabetes, and those with diabetes

15. **Cadore et al randomized frail older adults with a mean age of 91.9 to a control group or a twice-weekly training program of gait, balance, and power training. Outcomes for the group participating in the training program included: ________.**
    a. Physical performance, as measured by chair rise and balance, was significantly improved; falls were significantly decreased
    b. Significant increases in muscle strength and power; however, several injuries were reported
    c. Slight improvement on the timed-up-and-go test; no improvement on the timed-up-and-go dual task test
    d. All of the above

16. **The LIFE study focused on sedentary older adults ages 70-89 that were determined to be at risk for mobility disability, comparing those in a 12 month multi-component exercise intervention with a control group that received health education. At the end of the 12 months, outcomes included: ________.**
    a. Prevalence of frailty and the number of frailty criteria present had significantly decreased in the intervention group
    b. Prevalence of frailty had significantly decreased in the intervention group; the number of frailty criteria present had significantly decreased in both groups
    c. Prevalence of frailty had significantly decreased in the intervention group; the number of frailty criteria present remained constant
    d. Prevalence of frailty remained constant in the intervention group

17. **Senior athletes differ from their younger athletic peers due to age-related physical changes. Physical therapists should remember that ________.**
    a. Due to reduced bone density and increased ligamentous stiffness, older adults might be less likely to sustain a fracture versus a sprain or avulse a tendon rather than strain a muscle
    b. Older adults may be more prone to overuse injuries due to the increasing stiffness of collagen, reduced muscle mass, and/or altered movement patterns
    c. Senior athletes are rarely aware of the impact of rapid detraining on their athletic careers and may delay returning to their sport
    d. None of the above

18. **An injury-prevention strategy for senior athletes is to train at lower intensities. One way to monitor intensity is through the talk test: the ability to comfortably carry on a conversation during exercise correlates with ________.**
    a. High intensity
    b. Low intensity
    c. Moderate intensity
    d. Variable intensity

19. **Senior athletes may be concerned that strength training may limit aerobic conditioning. The evidence finds ________.**
    a. A significant decrease in cardiovascular endurance in older adults who engage in regular strength training
    b. A significant increase in cardiovascular endurance in older adults who engage in regular strength training
    c. A slight decrease in cardiovascular endurance in older adults who engage in regular strength training
    d. No change in cardiovascular endurance in older adults who engage in regular strength training

20. **Given that senior athlete data is still emerging and highly trained older adults have similar profiles to younger adults, examining data from younger cohorts can be useful. Mikkola et al examined a cohort of younger cross-country skiers in which the control group continued their typical endurance training regime and the intervention group replaced 27% of their endurance training with explosive strength training of the lower extremities. At the end of 8 weeks, outcomes included: ________.**
    a. Due to the reduction in the amount of endurance training, VO2max declined in the explosive-training group
    b. The explosive-training group experienced less economy in cross-country skiing performance
    c. The explosive-training group experienced significant improvement in explosive force production
    d. All of the above

ANSWER SHEET

First Name: ______________________ Last Name: ______________________ Date: __________

Address: ____________________________________ City: ______________________

State: ______________________ ZIP: ____________ Country ______________________

Phone: ______________________ Email: ____________________________________

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Clinical Fellow: Supervisor name and license/certification # ______________________

Graduate Student: University name and expected graduation date ______________________

** See instructions on the cover page to submit your exams and pay for your course.

By submitting this final exam for grading, I hereby certify that I have spent the required time to study this course material and that I have personally completed each module/session of instruction.

Exercise Training-Based Interventions for the Older Adult - Final Exam

1. Ⓐ Ⓑ Ⓒ Ⓓ	5. Ⓐ Ⓑ Ⓒ Ⓓ	9. Ⓐ Ⓑ Ⓒ Ⓓ	13. Ⓐ Ⓑ Ⓒ Ⓓ	17. Ⓐ Ⓑ Ⓒ Ⓓ
2. Ⓐ Ⓑ Ⓒ Ⓓ	6. Ⓐ Ⓑ Ⓒ Ⓓ	10. Ⓐ Ⓑ Ⓒ Ⓓ	14. Ⓐ Ⓑ Ⓒ Ⓓ	18. Ⓐ Ⓑ Ⓒ Ⓓ
3. Ⓐ Ⓑ Ⓒ Ⓓ	7. Ⓐ Ⓑ Ⓒ Ⓓ	11. Ⓐ Ⓑ Ⓒ Ⓓ	15. Ⓐ Ⓑ Ⓒ Ⓓ	19. Ⓐ Ⓑ Ⓒ Ⓓ
4. Ⓐ Ⓑ Ⓒ Ⓓ	8. Ⓐ Ⓑ Ⓒ Ⓓ	12. Ⓐ Ⓑ Ⓒ Ⓓ	16. Ⓐ Ⓑ Ⓒ Ⓓ	20. Ⓐ Ⓑ Ⓒ Ⓓ

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EXERCISE TRAINING-BASED INTERVENTIONS FOR THE OLDER ADULT

(3 CE HOURS)

COURSE EVALUATION

Learner Name: ______________________________

	Disagree				Agree	
Orientation was thorough and clear	1	2	3	4	5	
Instructional personnel disclosures were readily available and clearly stated	1	2	3	4	5	
Learning objectives were clearly stated	1	2	3	4	5	
Completion requirements were clearly stated	1	2	3	4	5	
Content was well-organized	1	2	3	4	5	
Content was at or above entry-level knowledge	1	2	3	4	5	
Content was substantiated through use of references, footnotes, etc.	1	2	3	4	5	
Content reflected stated learning objectives	1	2	3	4	5	
Exam assessed stated learning objectives	1	2	3	4	5	
Exam was graded promptly	1	2	3	4	5	
Satisfied with learning experience	1	2	3	4	5	
Satisfied with customer service (if applicable)	1	2	3	4	5	n/a

What suggestions do you have to improve this program, if any?

____

____

What educational needs do you currently have?

____

____

What other courses or topics are of interest to you?

____

____