Progress in Cardiovascular Diseases 77 (2023) 25–36

Contents lists available at ScienceDirect

Progress in Cardiovascular Diseases

journal homepage: www.onlinepcd.com

Musculoskeletal exercise: Its role in promoting health and longevity

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ARTICLE INFO

Keywords:
Exercise
Resistance exercise
Strength training
Cardiovascular disease

ABSTRACT

Resistance training (RT) is an often ignored but essential component of physical health. The functioning of the musculoskeletal system declines with age, resulting in sarcopenia, loss of muscle strength and power, decrease in muscle flexibility and balance. Other pertinent age-related changes include decline in basal metabolic rate, increase in fat mass, and decrease in bone mineral density. Such primary aging can be accentuated by the concomitant presence of comorbid conditions, such as insulin resistance and diabetes, obesity, inflammatory conditions, and physical inactivity (PI). The latter is often promoted by the presence of musculoskeletal conditions, such as osteoarthritis, back pain, and osteoporosis, which are quite common in society. RT can diminish long-term joint stress, "resist" age-related physiological deterioration and improve health outcomes through its ability to increase muscle strength and mass, balance the distribution of forces within a joint, increase basal metabolic rate and bone density, reduce body fat and cardiac risk factors, enhance endothelial function, and promote cognitive function and psychological well-being. Accordingly, health providers should screen for PI, lack of RT, and mobility risks using short screening questions, and employ simple functional tests, when indicated, to evaluate patients for impairment in gait, muscle strength, flexibility, and balance. This review also provides general principles for initiating and conducting RT and provides general and specific examples of resistance training programs, which should be individualized for patients through the evaluation and guidance by appropriate health providers, physical therapists, and certified trainers.

Contents

Physical exercise, healthy nutrition, and restorative sleep are essential pillars of health promotion. While performing resistance training (RT) is considered part of physical exercise, it deserves consideration as its own domain for health promotion. This is so for a few reasons. First, it is quite natural to take our mobility and musculoskeletal functioning for granted. As a result, attention to musculoskeletal health is often ignored until clinical problems emerge. Second, whereas performance of aerobic activities is relatively straightforward, proper RT

Abbreviations: ACSM, American College of Sports Medicine; BMI, body mass index; CRF, cardiorespiratory fitness; CVD, cardiovascular disease; LBP, lower back pain; METs, metabolic equivalents; OA, osteoarthritis; PI, physical inactivity; RT, resistance training; T2D, type 2 diabetes; TUG, Timed Up and Go test.

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https://doi.org/10.1016/j.pcad.2023.02.006
0033-0620/

generally requires acquired knowledge to understand the proper techniques for performing muscle strengthening correctly. Third, the benefits of strength training are profound and synergistic to the benefits afforded by aerobic exercise and thus deserve to be emphasized.[1,2]

The musculoskeletal system is a wondrously functional system, comprised of muscles, bones, joints, tendons, ligaments, fascia, and neuromuscular interface, which together support a person's stability, mobility, and aerobic and anaerobic capacity, and provide structural protection for the viscera. Additionally, skeletal muscles are metabolically active and contribute to the proper functioning of insulin and glucose regulation, fatty acid oxidation, and other metabolic functions.[3]

The prevalence of clinical musculoskeletal disorders is widespread within society, with 50% of the United States population having one or more chronic musculoskeletal conditions.[4] Back pain, chronic joint pain, and arthritis are particularly frequent musculoskeletal disorders, as common as hypertension in self-reported prevalence[5] (Fig. 1). Various factors contribute to today's high rate of musculoskeletal conditions. These include the recent rise in obesity as a global pandemic, including its increasing prevalence in younger individuals who may live for many years with the physiological and mechanical consequences of obesity. Moreover, there has been a concomitant marked rise in the prevalence of type 2 diabetes (T2D), largely due to the rise in obesity and metabolic syndrome. In addition, sedentary behaviors, including prolonged sitting, are commonplace and contribute to musculoskeletal risk. Finally, the percent of older individuals, with their greater propensity towards musculoskeletal conditions, is increasing within society.

There are multiple reasons why cardiologists and related specialists should place increasing emphasis on musculoskeletal health. The adverse outcomes that stem from cardiovascular disease and musculoskeletal disorders share common root causes, such as systemic inflammation. These same root causes are shared by other lifestyle-related chronic diseases including obesity, pre-diabetes/T2D, hypertension, hyperlipidemia, cardiovascular disease (CVD), and some cancers. The lifestyle factors that contribute to these conditions include physical inactivity (PI; which includes both aerobic and RT) and poor nutrition, poor sleep, high stress, poor social connections and use of tobacco and excessive alcohol. Various indices of musculoskeletal function, including poor muscle strength, are predictors of CVD.[6] Recent data suggest that factors that relate to mobility impairment are becoming a more predominant driver of mortality among CVD patients.[7] Finally, whereas enhancing patients' level of physical activity (PA) is a cardinal target for primary and secondary CVD prevention, success in this regard is dependent on patients being relatively free from major mobility impediments due to musculoskeletal diseases.

In this narrative review, we overview the primary and secondary aspects of aging that affect musculoskeletal functioning, the importance of musculoskeletal disorders as they relate to mobility, the diverse clinical benefits of resistance training, and the commonly used methods for assessing musculoskeletal dysfunction. We then suggest general principles for incorporating RT into one's lifestyle.

Primary aging and the decline in physiological and musculoskeletal function

The aging process can be divided into factors associated with “primary” versus “secondary” aging. Primary aging characterizes the inevitable deterioration that takes place in cellular structure and biological functions, independent of disease, lifestyle, or environmental influences. Secondary aging is the additional deterioration that exacerbates primary aging because of disease processes, adverse lifestyle behaviors, or environmental influences. Table 1 lists principal manifestations of primary aging. A cardinal aspect of aging is the progressive loss of lean

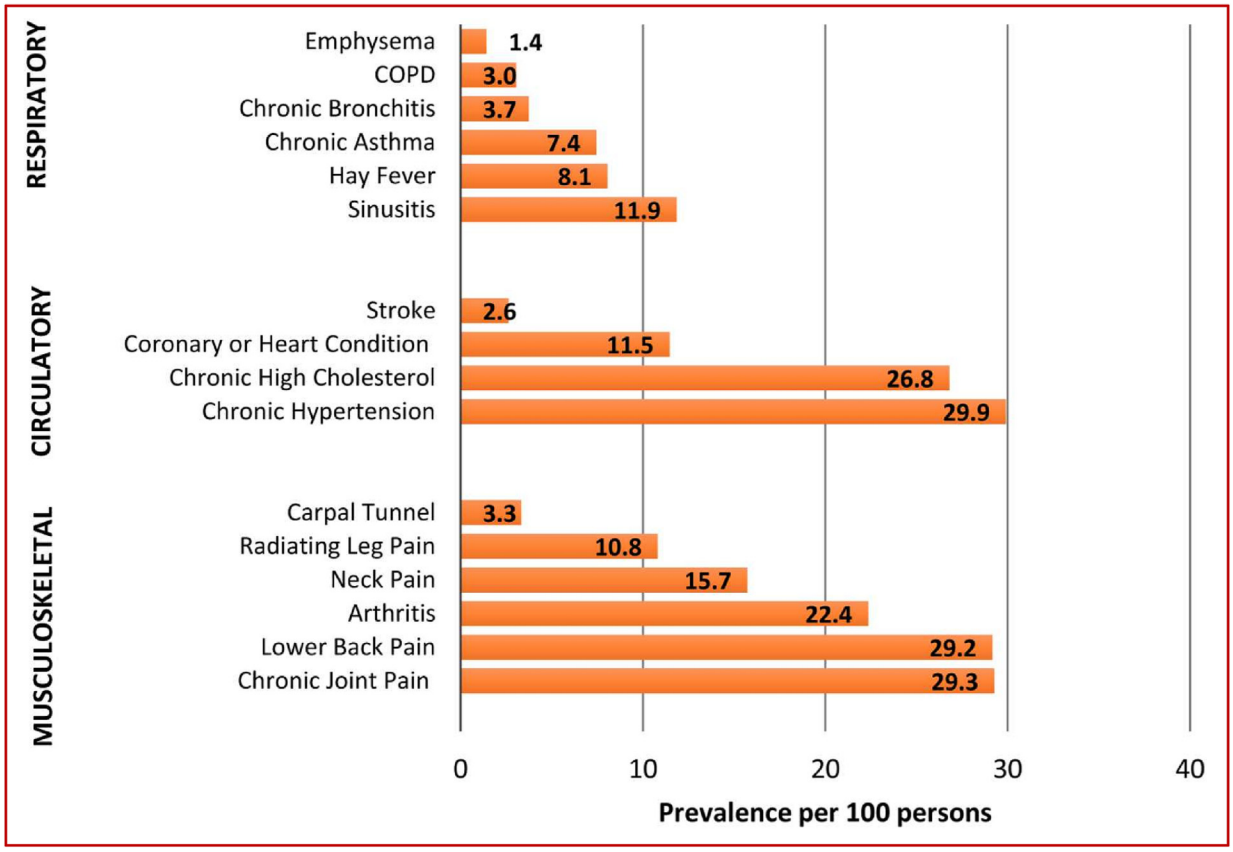

Fig. 1. In the 2015 National Health Interview Survey, the most common self-reported medical conditions included hypertension, hypercholesterolemia, and three orthopedic conditions: low back pain, chronic joint pain, and arthritis. (Reproduced from Reference 5).

Table 1
Age-related organ and cellular level changes related to cardiac function and disease risk.

- Decrease in muscle mass, strength, and quality
- Decrease in bone mineral density
- Decrease in balance and flexibility
- Declining basal metabolic rate
- Age related increases in low level inflammation
- Decline in peak oxygen capacity
- Decrease in arterial compliance
- Increase in endothelial dysfunction
- Increased risk of insulin resistance and type 2 diabetes

muscle mass.[8] In the absence of resistance training, muscle mass is estimated to decrease by approximately 3–8% per decade after age 30 with a greater rate of decline after age 60.[9,10] Both muscle strength and power decline and the composition of muscle changes leading to increasing infiltration of fat into skeletal muscles.[11] Studies suggest an association between the magnitude of intermuscular fat accumulation and muscle strength and performance[11–13] (Fig. 2).

Muscle flexibility declines with age, joint stiffness increases, and there is a progressive loss of balance. This increases the risk of falls among older adults. Overall, approximately one-third of adults ≥65 years of age experience at least one fall per year, with serious injuries occurring in approximately 10% of falls.[14] Aging is also associated with a decrease in bone mineral density of 1–3%/year,[15] small reduction in stature (due to kyphosis and disc height loss), and increased risk for osteoporosis.

The decrease in muscle mass with age is accompanied by a progressive increase in fat mass, which generally exceeds the loss in muscle mass.[16] Due to the counterbalancing changes in muscle and fat mass, body mass index (BMI) becomes a less reliable reflection of body composition among older adults.

Basal metabolic rate declines between 2 and 3% per decade,[17] with muscle loss being the greatest contributor to this decline. This reduction increases the propensity towards weight gain with age.

Aging is associated with a risk for low level systemic inflammation[8,18] and increased risk for developing insulin resistance and T2D.[19–21] Various pathophysiological changes in aging muscle, such as mitochondrial dysfunction, intracellular lipid accumulation, and inflammation contribute to insulin resistance in muscle tissue.[22] From a cardiac perspective, important changes associated with aging include an intrinsic decline in the compliance of large arterial vessels, such as the aorta, and increase in endothelial dysfunction.[23] In addition, peak oxygen capacity declines approximately 10% per decade with accelerating declines among older adults.[24,25]

Acceleration of age-related declines in physical health

Disease and adverse lifestyles can accelerate many aspects of primary aging processes on a cellular and organ level, with adverse consequences for musculoskeletal function. For instance, both diabetes and obesity accelerate muscle loss, as does PI.[8,26–28] Other disease processes associated with inflammation, such as rheumatoid arthritis, also accelerate sarcopenia.[28–30] The combination of obesity and sarcopenia among older adults may lead to a syndrome of "sarcopenic obesity", in which one condition may beget the other in a vicious cycle of deterioration, as illustrated by Kalyani et al.[28] (Fig. 3). The combination of obesity and sarcopenia leads to worse clinical outcomes than either condition alone.[28,31,32]

Musculoskeletal disorders

The development of musculoskeletal disorders within the spine and lower limbs is intimately related to future CVD risk because of the resultant increase in PI and promotion of sedentary behavior. The most common musculoskeletal conditions that increase mobility risk include osteoarthritis (OA), back pain, and osteoporosis. Because of the risks that these musculoskeletal conditions impose on global health of patients, front line health care providers need a working knowledge of how to detect and direct treatment for these three musculoskeletal disorders.

OA is the most common joint disease, currently affecting 1 in 2 adults in the United States and involves a complex mechanism of joint degradation and inflammation that starts with cartilage injury followed by wear and tear. This degradative process leads to an abnormal response to mechanical stressors causing further cartilage loss that increases with age, leading to subsequent joint instability and pain.[33] The intra-articular environment is altered in OA, with upregulation in

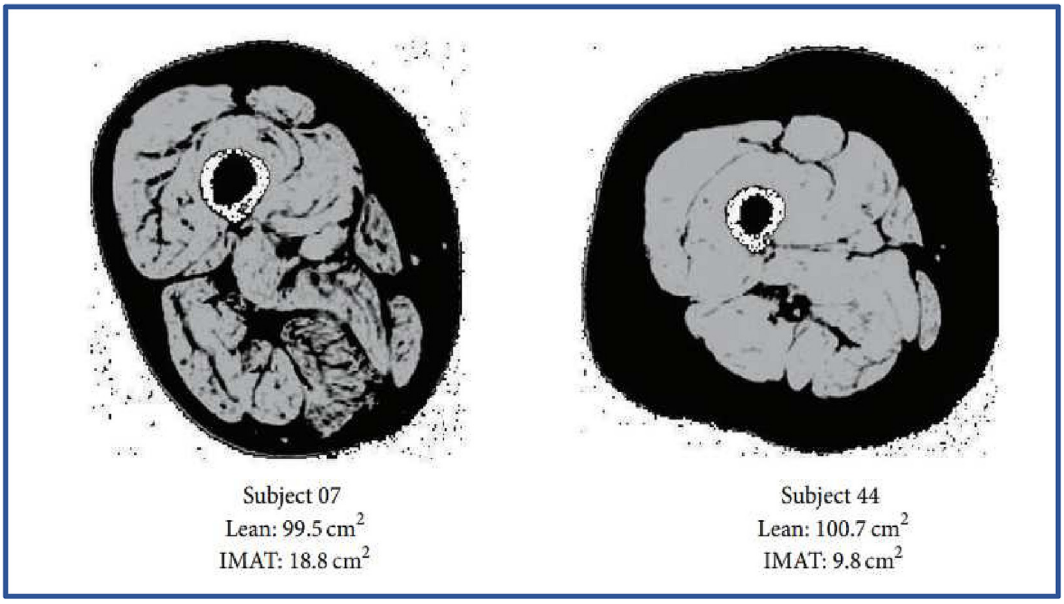

Fig. 2. Shown are the cross-sectional magnetic resonance images in two women with similar age, body mass index, and levels of lean muscle mass, but different levels of intermuscular fat. Lean muscle tissue appears as gray and intermuscular fat (IMAT) are the black areas within the lean muscle. Subject 7, as shown in the left panel, has twice the level of IMAT in her thigh as does subject 44, shown in the right panel. Subject 7 had decreased mobility function. (Reproduced from Reference 11, with permission).

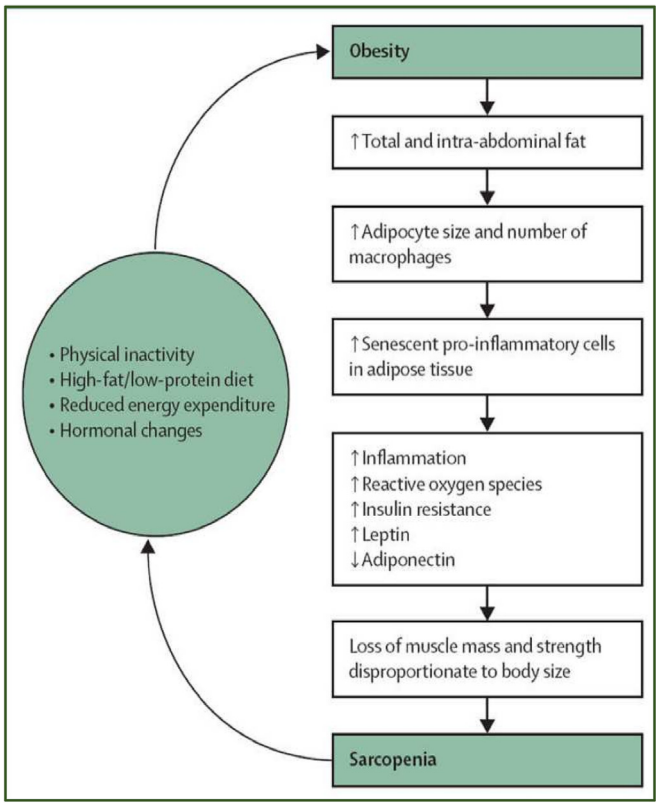

Fig. 3. The depiction of how the co-occurrence of obesity and sarcopenia might lead to a vicious cycle of physiologic deterioration. Obesity is associated with increased size and dysfunction of adipocytes, resulting in inflammation, reactive oxygen species, and insulin resistance, among other metabolic changes. This leads to loss of muscle mass and strength relative to the size of obese patients, resulting in a tendency towards reduced physical activity and energy expenditure which may beget further obesity. (Reproduced from Reference 28, with permission).

inflammatory mediators as well as catabolic signaling that outweighs the anabolic and anti-inflammatory mediators.[34] Radiographic findings of OA are joint space narrowing, osteophyte formation, subchondral sclerosis, and cysts. Physical therapy is an important treatment modality for OA, with an aim to build the strength of the muscles that can alleviate the stress on the affected joint. For example, with knee OA physical therapy is also used to improve pain tolerance through structural stabilization, as there is a clear relationship of knee extensor weakness and increased pain in patients with knee OA.[35] Other treatments for OA are listed in Table 2**.** These include treatments that are aimed at the altered intra-articular environment including aspiration of joint effusions as well as injection of analgesics, corticosteroid, hyaluronate preparations, and potential use of novel regenerative treatments, such as platelet rich plasma. The evidence for the benefits of hyaluronate preparations are mixed but can be an alternative for patients who should avoid steroids. The outcomes and benefits of platelet-rich injections for peripheral joint OA are still to be established and are not universally available in the United States because they are not reimbursed by third party health insurance coverage.

Like OA, low back pain (LBP) is common and a leading cause of disability worldwide. Axial LBH includes pain from the 12th rib to the inferior gluteal fold, and can refer to pain into the buttocks, legs, and pelvis. It is important to differentiate axial LBP versus LBP associated with gluteal and lower extremity symptoms in order to best direct treatment. Over time, LBP may become chronic due to factors such as central sensitization and may fall under the category of nociplastic pain.[36] A wide variety of treatments are available for managing LBP, as listed in Table 3**.**

These include therapeutic exercises, use of a variety of medications, and various non-operative and operative treatments. Additionally, biopsychosocial factors such as fear, anxiety, mood disturbance, social and environmental factors influence LBP treatment outcomes and should be addressed as part of comprehensive treatment.[37] Chronic pain can lead some people to develop fear avoidance and catastrophizing behaviors and beliefs and can impair a patient's desire to engage in an exercise program further enhancing the cycle of pain, mobility impairment, and CVD.

Osteoporosis is a common chronic musculoskeletal condition that is characterized by reductions in bone mass and bone quality. The microarchitectural changes that occur with osteoporosis lead to decreased bone strength and a high susceptibility to fracture. Because osteoporosis is asymptomatic, many adults are not aware that they have it. Postmenopausal women and older adults are at greatest risk for developing osteoporosis. Approximately 1 in 2 women and 1 in 4 men over the age of 50 will develop an osteoporosis-related fracture.[38] The bones most susceptible to fracture are those of the hip and spine. If low bone density is suspected or there is a significant risk of fractures or gait disorder, or there has been long-term use of medications that can promote sarcopenia, there should be a low threshold for referring patients for dual-energy X-ray absorptiometry. Osteoporosis also increases the risk of frailty and leads to greater premature mortality.

The clinical benefits of RT

RT can diminish the rate of physiological deterioration associated with primary and secondary aging. The ways in which musculoskeletal exercises may essentially "resist" the usual aging processes and provide clinical benefits are summarized in Fig. 4**.** RT stimulates an increase in muscle mass and quality by providing stimuli to the motor unit that results in muscle fiber hypertrophy, greater neuromuscular control, and strength gains. Strength is often associated with muscle cross sectional area. The increase in muscle cross sectional area is a cumulative process including myofibrillar and sarcoplasmic hypertrophy. Tissue responses are largely regulated by insulin, amino acid availability, and mTOR (mammalian target of rapamycin).[39] At the extreme, those who are master athletes (i.e., athletes chronically training at high levels 4 to 5 times per week) may show only minimal reduction in muscle mass with age, which can contrast sharply with the muscle atrophy noted among sedentary older adults[40] (Fig. 5**).**

Table 2
Treatment options for osteoarthritis.

- Physical therapy and muscle strengthening protocols
- Topical and oral anti-inflammatories and analgesics for symptom control
- Aspiration of joint effusions
- Injection of analgesics, corticosteroid, and hyaluronate preparations
- Injection of novel regenerative treatments (e.g., platelet rich plasma) and others.
- Hip and knee arthroplasties

Table 3
Treatment options for lower back pain.

- Physical therapy exercise to condition core musculature
- Physical therapy exercise to stabilize and/or offload painful structures
- Non-steroidal anti-inflammatory medications
- Modalities, such as ice, heat, electrical stimulation, low level laser therapy
- Manual manipulation
- Neuropathic pain medications, analgesics, and muscle relaxants
- Zygapophyseal joint injections
- Radiofrequency neurotomy of the lumbar medial branch nerves
- Basivertebral nerve ablation
- Neuromodulation, and biologic treatments with limited efficacy
- Decompression and fusion of painful segments of the spine
- Microdiscectomy, kyphoplasty, laminectomy, and other novel procedures

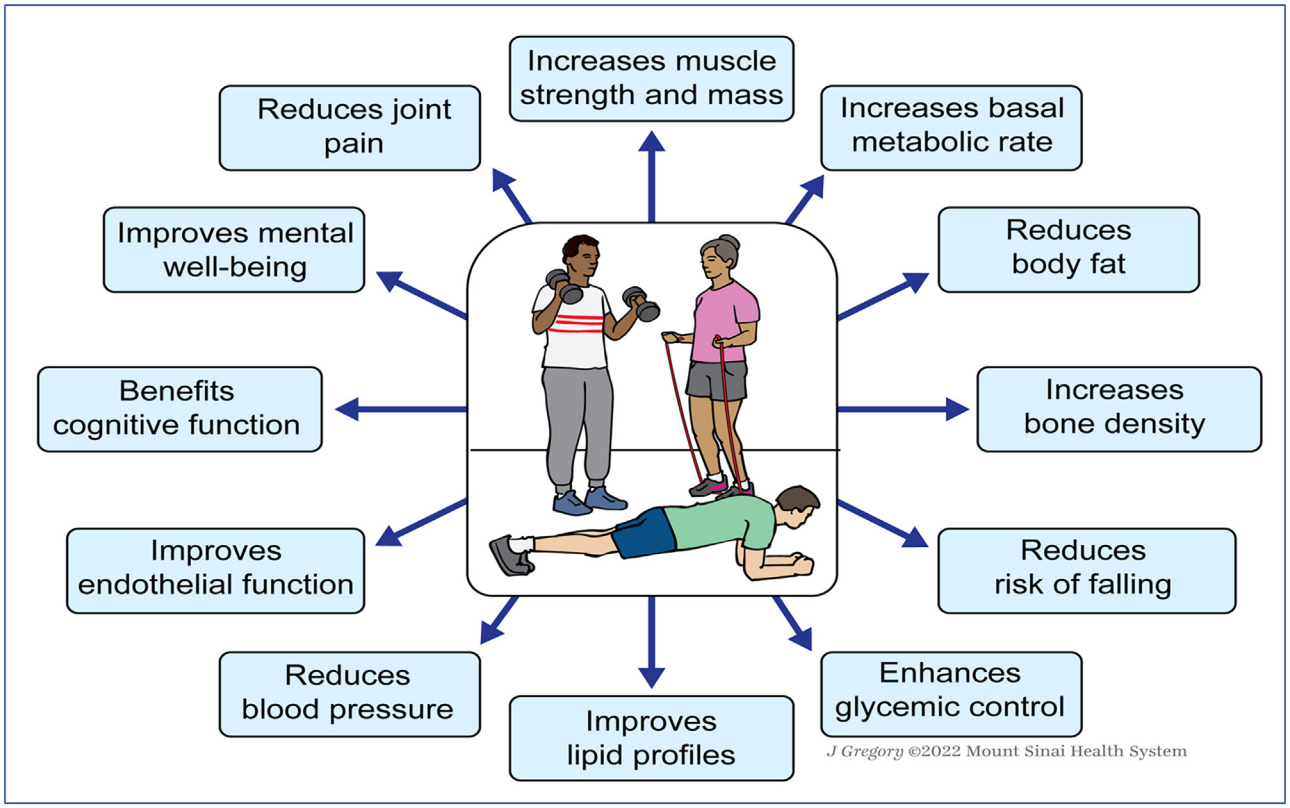

Fig. 4. The clinical benefits resulting from consistent resistance training.
(Illustration by Jill Gregory used with permission of © Mount Sinai Health System).

RT raises basal metabolic rate, due in part to, the greater tissue maintenance that follows from creating greater muscle mass. On an acute basis, RT induces tissue micro-trauma, with energy required for subsequent muscle remodeling. This increase in energy requirement may last for up to 72 h after a training session.[41] On a chronic basis, as muscle mass is accrued with training, it leads to a higher metabolic rate, allowing individuals to burn more calories without even trying.

RT can slow age-related loss in bone mineral density and is recommended for the treatment or prevention of osteoporosis. Studies have shown that bone mineral density increases by 1 to 3% in pre-and postmenopausal women after several months of RT.[15,42] Exercise provided in a community setting using high-velocity progressive RT and moderate-intensity multidirectional impact exercises as well as balance and mobility exercises are also beneficial for individuals with osteoporosis.[43] Participants in this exercise protocol demonstrated statistically significant changes in bone mineral density at the hip, lumbar spine, and decreases in total body fat mass, and increases in total body lean mass. Additionally, RT aids the reduction in fall risk among older adults.[14,44]

Like aerobic exercise, RT can improve lipid metabolisiom[45] and decrease the risk for metabolic syndrome and T2D.[46–48] For example, the utility of RT for preventing diabetes was assessed in the Women's Heart Study which followed 35,754 women for a mean of 10.7 years.[49] Compared to women who did not participate in RT, women who engaged in any strength training had a 30% lower risk of developing T2D during the follow-up period. The combination of aerobic exercise and RT can additively improve parameters of glucose-insulin homeostasis[45–47] (Fig. 6). Resistance training also improves endothelial function[50] and can improve resting blood pressure[51] and hyperlipidemia.[52]

Emerging literature suggests that engagement in regular exercise may improve cognitive abilities and be protective versus the development of dementia.[53–56] For example, Boyle et al. followed 900 community-based older individuals for a mean of 3.6 years following baseline muscle strength testing.[53] Each one unit increase in muscle strength at baseline was associated with an approximately 43% decrease in the risk for developing Alzheimer's disease and 33% reduction in the risk for developing mild cognitive impairment. The beneficial effect of RT on cognition is supported by recent meta-analyses,[57,58] and more research should further study this promising arena of potential benefit.

Clinical studies indicate that RT is associated with positive psychological benefits, such as higher self-esteem and sense of vigor, better sleep, more positive mood, and reduction in depressive and anxiety symptoms. For example, in a meta-analysis of 33 randomized clinical trials involving 1877 participants, resistance training was associated with a significant reduction in symptoms of depression with a moderate effect size.[59] These effects were noted regardless of participants' baseline health status. A systematic review of 16 studies has also noted a reduction of anxiety symptoms with resistance training, although further study is indicated.[60] A third meta-analysis of 19 randomized controlled trials has found that RT reduces depressive and anxiety symptoms among patients with musculoskeletal pain.[61]

Finally, as aforementioned, RT aids the treatment of specific musculoskeletal disorders. There is strong and consistent evidence that physical exercise decreases knee pain and improves the physical function of individuals with knee or hip osteoarthritis relative to individuals with OA who are less active.[62] Moderate-to-vigorous PA, as represented by a vigorous walk for 10 min once per week, can begin to mitigate functional limitations associated with knee osteoarthritis.[63] Additionally, based on evidence that knee extensor weakness confers an increased odds of developing symptomatic and radiographic knee osteoarthritis by around 30%,[64] muscle strengthening exercise should also be advocated as a prophylactic measure for reducing the risk of future arthritis among individuals who manifest weak knee extensor strength.

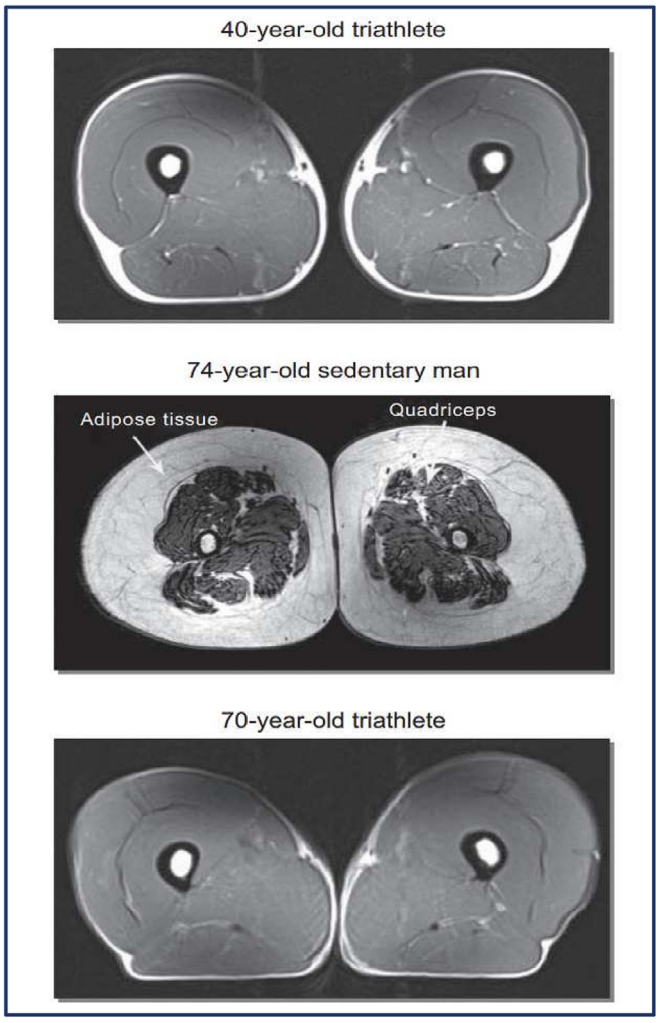

Fig. 5. Magnetic resonance imaging scans of the quadricep muscles from three subjects, including a 40-year-old triathlete (top image), 70-year-old triathlete (bottom image), and 74-year-old sedentary man (middle image). The triathletes were part of a study of forty master athletes, recruited on the basis of chronically training for fitness or sports competitions ≥4 or 5 times per week. There was a significant increase in adipose tissue (white regions) in the sedentary man which is not observed among the triathletes. (Reproduced from Reference 40, with permission).

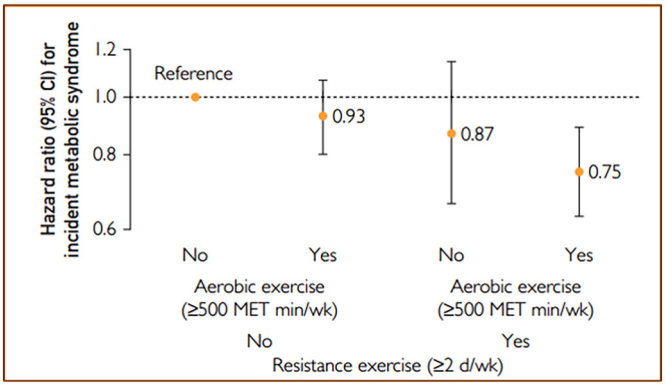

Fig. 6. Adjusted hazard ratios and 95% confidence intervals (vertical lines) for development of metabolic syndrome among 7418 individuals followed for a median of 4 years following a medical examination at the Cooper Clinic. The subjects were divided into four groups based on their self-reported participation in aerobic exercise and resistance training exercises. Shown from left to right are those who did not engage in aerobic or resistance training (reference group), those who engaged in aerobic but not resistance training, those who engaged in resistance but not aerobic training, and those who did both. The latter group had the lowest risk for developing metabolic syndrome during follow-up. (Reproduced from Reference 47, with permission).

Physical exercise is also an essential treatment for alleviating LBP. Additionally, PI is associated with narrower lumbar intervertebral discs, as well as a higher fat content in the paraspinal muscles and LBP. There is a dose-response relationship of PI with high-intensity LBP and disability.[65] Effects of a physical training program on functional capacity and LBP can maintain its benefits years after physical therapy intervention.[66] Combined forms of exercise have also been shown to improve bone density in the lumbar spine and femoral neck in early postmenopausal women,[67,68] a high-risk group for bone loss.

Screening for musculoskeletal disease

Screening patients for musculoskeletal conditions and emerging mobility limitations should be incorporated into the standard review of systems by physicians for middle-aged and older patients. Patients should be queried about any loss of energy or fatigue, change in weight, including unintended weight loss in older adults, and difficulties in PA.

The questions posed to patients should be more detailed among older adults given their higher frequency of mobility limitations. As patients age, the earliest functional limitations generally involve the lower limbs and manifest in progressive difficulty in walking over a distance, climbing stairs, or getting up from a chair. In order to screen for such pre-mobility limitations, patients can be asked if they have experienced some difficulty walking about a half mile (approximately 5–6 city blocks) or climbing a flight of stairs.[69] Patients can also be asked if they get more easily winded, which may indicate deconditioning or underlying medical conditions.

Patients may also be asked whether they tire more easily when standing for a period, which may indicate new or continued decrease in core strength. Patients should be screened for balance issues, a history of falls, and musculoskeletal pain. Patients complaining of these problems may be considered for referral to physical therapists, physiatrists, orthopedists, podiatrists, or rheumatologists for further evaluation. Patients should also be queried about types and intensity and frequency of exercises that they perform.[70]

Table 4 lists commonly used methods to assess various aspects of physical function. When indicated, cardiorespiratory fitness (CRF) can be objectively assessed by a variety of standard tests. The Bruce treadmill protocol provides an indirect but useful assessment of patients' maximal oxygen consumption (VO_{2max}) by assessing patients achieved metabolic equivalents (METs) of exercise. Achieved METs is a more powerful predictor of mortality compared to other CVD risk factors.[71] Older patients generally require lower intensity protocols.

The six-minute walk test involves having patients walk for six minutes at their own pace with the goal of determining how far they can walk. This test was initially developed to evaluate functional capacity among patients with heart failure or chronic respiratory diseases, but it also can be used to evaluate the functional capacity of older adults.

The Bruce treadmill exercise protocol or modified protocols are widely used as a standard means for provoking myocardial ischemia and assessing CRF during cardiac stress testing. However, an increasing percentage of patients referred for cardiac stress imaging procedures have required pharmacologic testing because of an inability to perform adequate treadmill exercise.[72,73] Patients who require pharmacologic testing are at substantially greater risk for future CVD events or premature mortality.[74–77]

Patients with poor exercise performance or requiring pharmacologic testing may benefit from other tests to evaluate the nature and degree of physical limitations that preclude the ability to exercise. Among these, assessment of patients' gait speed may be particularly useful. This assessment is not an aerobic test but rather reflects potential

Table 4
Common methods for assessing exercise functional capacity and musculoskeletal function.

ASSESSMENT OF EXERCISE FUNCTIONAL CAPACITY OR ENDURANCE	
Standard Bruce treadmill protocol	Widely used for cardiac stress testing, involving progressive increase in speed and incline every 3 min.
Modified Bruce protocol, Balke, Naughton, and other individualized protocols	Treadmill protocols using lower rate of exercise provocation, used to accommodate older patients or those who are deconditioned or infirm.
Six minute walk test	A submaximal exercise test that can be used to assess functional capacity and endurance in cardiopulmonary or older patients
ASSESSMENT OF GAIT	
Assessment of gait speed	Timed walk over short distances, such as 4 m (~13 ft). Is a non-aerobic exercise that can gauge the functional status of older adults
Visual assessment of gait pattern	Visual assessment of gait speed or inspection for irregularities, such as shuffling gait, walking with imbalance, stooped posture, flat footedness, foot drop, Trendelenburg or compensated Trendelenburg gait, kyphoscoliotic changes that may shift center of mass, and pelvic obliquity.
ASSESSMENT OF MUSCLE STRENGTH	
Assessment of grip strength	Evaluated using hand-held dynamometer, squeezed tightly, with multiple readings obtained from both hands. Reflects overall muscle strength.
Assessment of lower limb strength	Can evaluate by assessing quadricep strength in performing walking lunges or a double leg squat. Can evaluate number of sit-to-stands during 30-s to assess for leg strength and endurance
EVALUATION OF BALANCE	
Standing balance tests	Examples include standing on one foot for 10 s minimum, standing with eyes closed, tandem standing, Romberg's test, or performance of tandem walking
Multi-domain functional assessments	
Short physical performance battery (SPPB)	A battery of 3 tests that assess lower extremity function: evaluation of gait speed, performance of repeated chair rise, and standing balance
Timed-up and Go Test	Rise from armless chair, walk 10 ft, turn around and walk back to chair. Integrates assessment of gait speed and balance.

difficulty in one or more of various systems that may relate to walking, including the function of the cardiac, pulmonary, neural, and musculoskeletal systems. Gait speed can be objectively evaluated over various short distances, such as a 4-m test (~13 ft). Even in the absence of formal assessment of patients' gait speed, observation of patients' gait speed at the time of office visits can often reveal patients who have apparent slowness of gait or clinical gait issues. Meta-analyses demonstrate that objectively or subjectively assessed walking speed is strongly related to the risk for future morbidity and mortality.[78–80]

In addition to gait assessment, musculoskeletal strength can also be readily assessed in patients by evaluating their grip strength using a hand-held dynamometer. Various studies indicate that grip strength is a useful indicator of overall muscle strength.[81,82] Recent large cohort studies and meta-analyses have linked hand grip strength to adverse clinical outcomes, including overall mortality and CVD risk[83–86] (Fig. 7). There is also increasing evidence that poor lower limb strength is associated with higher mortality risk.[87–90] In addition, testing for knee extensor muscle weakness may be used as a screening test because it is a predictor of increased risk for developing knee OA.[64,91]

The assessment of balance is important among older adults given the increasing risk for falls with aging.[14] It can be assessed by a variety of simple tests. For example, balance can be assessed by asking patients to stand on one leg or attempt to stay balanced while positioning one foot in front of the other. The Romberg test is another simple test that can be performed in the office as a screening tool. Tandem gait should be assessed, and poor performance may suggest myelopathy, neuropathy or other neurologic conditions requiring further evaluation. Single leg stance should be assessed for length of successful performance and presence of a pelvic drop to one side, the Trendelenburg sign. This may indicate gluteal weakness which can be a risk factor for falls and a target for RT.

Objective tests can also be combined to provide a more comprehensive assessment of musculoskeletal function. A common test in this regard is the short physical performance battery, which combines the assessment of patients' gait, repeated chair rise, and standing balance. Another test, the Timed Up and Go test (TUG), combines the assessment of patients' balance and gait speed. This test asks patients to rise from an armless chair, walk 10 ft, turn around and walk back to a sitting position, all performed without using the upper extremities to provide force. A patient that takes >12 s to perform the TUG is at risk for falling.[92]

Guidelines for the promotion of musculoskeletal health

Initiating RT requires attention to correct form and technique and should be conducted under the supervision of a qualified professional for those not familiar with strength training. The treatment of musculoskeletal disorders requires the skilled evaluation and guidance of physiatrists, orthopedists, sports medicine physicians, or podiatrists, and related specialists, exercise kinesiologists and physical therapists, for instruction and supervision.

General principles for performing strengthening exercises, as recommended by the American College of Sports Medicine[93] and summarized by Westcott et al.,[15] are shown in Fig. 8**.** Individuals should seek to perform 8–10 resistance exercises that together address each major muscle group. RT should be performed two or three times per week but on non-consecutive days. Two to three sets of each exercise should be performed, with each set generally consisting of 8–12 repetitions, performed in a controlled manner through a full range of motion at approximately 60–80% of maximal resistance.

It is recommended that individuals exhale during lifting (concentric action) and inhale during lowering (eccentric action). Breath holding throughout the duration of a repetition is not recommended, as this

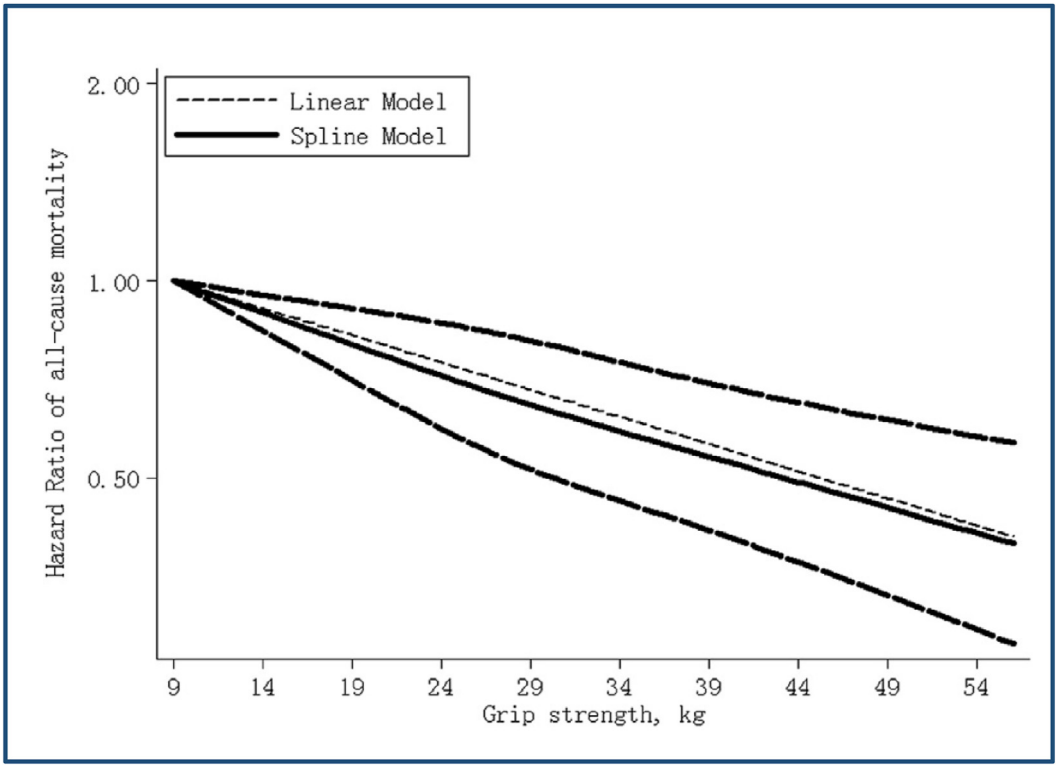

Fig. 7. Dose-response relationship between degree of grip strength (x-axis) and hazard ratio for mortality (Y axis) as observed in a meta-analysis of 42 studies. The solid line represents the estimated relative risk, and the long dashed lines represent the 95% confidence intervals. The short-dashed line represents the linear relationship, indicating a progressive decrease in mortality risk with increasing grip strength at baseline testing. (Reproduced from Reference 84 with permission).

can lead to a large increase in blood pressure and intraspinal pressure. As strength increases, the degree of resistance should be increased so that the last effort of each set remains challenging. Being able to complete >8–12 repetitions with ease means that the amount of resistance is inadequate.

Progression can be achieved by adding either more repetitions to a given resistance exercise, more sets of the exercise, more weight, decreasing rest times, or by adding additional exercises that work the same muscle group.

Exercises of lesser intensity with a gradual guided increase should first be employed to reduce the risk of injury and undue muscle soreness among individuals who are just beginning to initiate musculoskeletal exercise.

To benefit from musculoskeletal training, it must be performed on a regular basis. Thus, it is important to adopt a RT regimen that feels reasonable from a time, effort, and convenience perspective. To this end, one does not need specialized resistance machines to perform the common resistance exercises that optimize health. Using body weight, elastic bands, and use of free weights, such as dumbbells, medicine

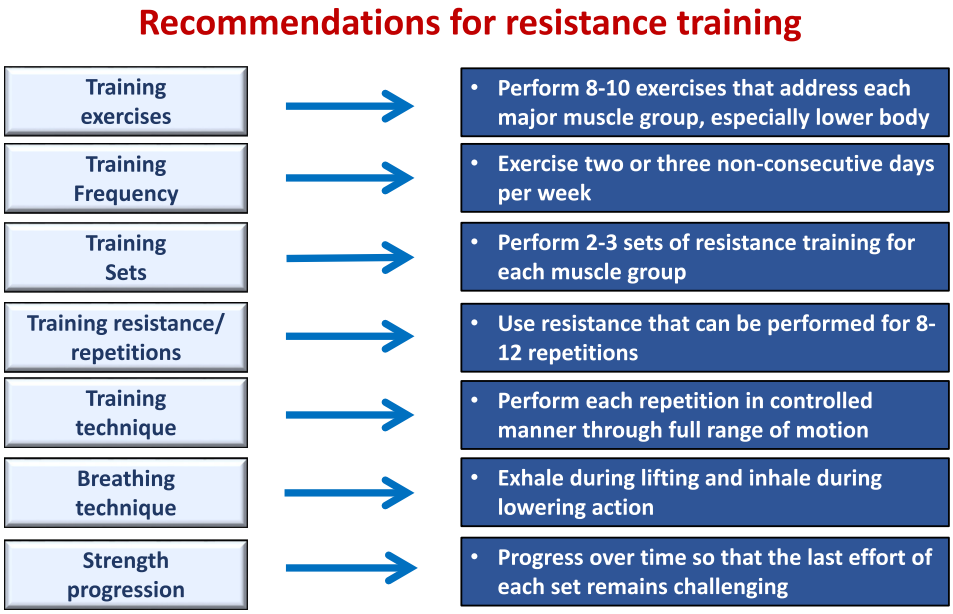

Fig. 8. Guidelines for performance of musculoskeletal exercises, as recommended by the American College of Sports Medicine. (Derived from References 15 and 93).

Table 5
Example of a training routine, organized into alternating day exercises

A. Potential format of a resistance training routine (10–12 exercises/day)*

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Legs	Chest/back	REST	Legs	Chest/back	REST
Balance	Arms		Balance	Arms	
Core	Core		Core	Core	
Stretches	Stretches		Stretches	Stretches	

* It is best to allow at least 48 h between exercises to permit appropriate recovery.

B. Example of an illustrative resistance training routine based on above format *

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
LEGS	**CHEST/BACK**	**REST**	**LEGS**	**CHEST/BACK**	**REST**
Squats	Push ups		Squats	Push ups	
Reverse lunges	Two armed rows		Reverse lunges	Two armed rows	
Step ups	Chest fly		Step ups	Chest fly	
Heel raises	Lat pulldowns		Heel raises	Lat pulldowns	
Glute bridges			Glute bridges		
BALANCE	**ARMS**		**BALANCE**	**ARMS**	
Single leg stand	Bicep curls		Single leg stand	Bicep curls	
Standing hip abduction	Triceps overhead press		Standing hip abduction	Triceps overhead press	
Side steps with bands	Overhead military press		Side steps with bands	Overhead military press	
	Lateral raise			Lateral raise	
CORE	**CORE**		**CORE**	**CORE**	
Planks	Pelvic tilts		Planks	Pelvic tilts	
Side planks	Bird dog		Side planks	Bird dog	
Trunk rotation	Dead bug		Trunk rotation	Dead bug	
STRETCHES	**STRETCHES**		**STRETCHES**	**STRETCHES**	
Calf stretch	Side bending		Calf stretch	Side bending	
Quadriceps	Wall angels		Quadriceps	Wall angels	
Hamstrings			Hamstrings		

* Note: This example is just illustrative. Specific exercise regimens should be developed under health provider guidance. For leg, chest, back, and arm exercises, allow 90–120 seconds between each of 3 sets. For core exercises, hold each position for 8–10 seconds, and as conditioning improves, progress the amount of time the position is held. For stretches, hold each one for 20 seconds with progression into further range of motion over time; repeat three times.

balls and kettlebells, can suffice to create a highly effective resistance training protocol. For those who are time pressed, some resistive exercises can be incorporated into various aspects of one's lifestyle. For example, one can incorporate squats, lunges, wall pushups, or similar exercises while taking a break at work. Stair climbing and weight bearing calisthenics may also be similarly incorporated.

Time permitting, individuals should seek to perform exercises that help condition each major muscle group of the body, including the arms, shoulders, chest, back, the abdomen, back, hips and legs. A typical resistance routine, usually involving ~3 sets of each exercise, can often be conducted in ~30 min. Routines can vary widely. Examples of exercises that address the major muscle groups are shown in Table 5 and Fig. 9, but many permutations of these examples can be adopted. Many of the listed exercises help to simultaneously condition multiple muscle groups.

Resistance routines should be developed under expert health supervision according to appropriate age and medical considerations. It is important to include stretching exercises to maintain muscle flexibility, joint range of motion, and reduce stiffness and tightness that may occur especially as a new strength routine is being initiated.

Eccentric RT is important to include in a RT exercise program because it can lead to elongation of the muscle belly enabling muscle contraction efficiency. This can protect tendons as load increases due to the propensity for poor form and high volume to lead to tendon wear. A specific example of practical use of eccentrics includes the eccentric control of the femur which is responsible for stability during the gait cycle.

In addition to strengthening exercises, adults should also include exercises that help maintain and promote balance and seek guidance to replicate, support, and strengthen activities of daily living that may be becoming difficult for them.

RT should be complemented by the performance of regular aerobic exercise or PA. Aerobic exercise induces cardiovascular adaptations that increase peak oxygen consumption but does not substantially improve muscle strength. RT accomplishes the opposite.[94] The combined benefits of aerobic exercise and resistance exercise are synergistic. Their combined performance results in a lower risk of death, CVD, cancer, T2D, and other lifestyle-related chronic diseases compared to the performance of either type of exercise alone.[1]

Weight management is an important aspect of musculoskeletal health maintenance. In addition to the general medical risks associated with obesity, obesity is a well-recognized contributor to the development of OA and disorders of bone microarchitecture. Individuals with a higher BMI have a significantly higher relative risk of developing severe knee OA, as well as developing back pain due to a higher structural load on the spine and inflammatory properties of the fat cells.

Finally, it should be recognized that neither age nor medical status is an absolute deterrent to initiating RT. Even elderly adults with poor baseline function may benefit from strength training. The modest increase in strength that may occur among frail older adults can enhance their ability to perform essential tasks like making a bed or carrying groceries. These activities enable independent living.

In a study evaluating quadriceps cross sectional area in response to 12 weeks of dedicated quadricep training, older adults developed skeletal muscle hypertrophy in response to RT.[95] And in a randomized study of elderly nursing home residents,[96] those who underwent progressive RT exercise had approximately 100% increase in muscle strength, as well an increase in gait velocity, and stair climbing ability.

The message of such studies is clear. When it comes to protecting musculoskeletal function, it is never too late to start! RT is an important lifestyle exercise component for people to adopt to prevent, manage

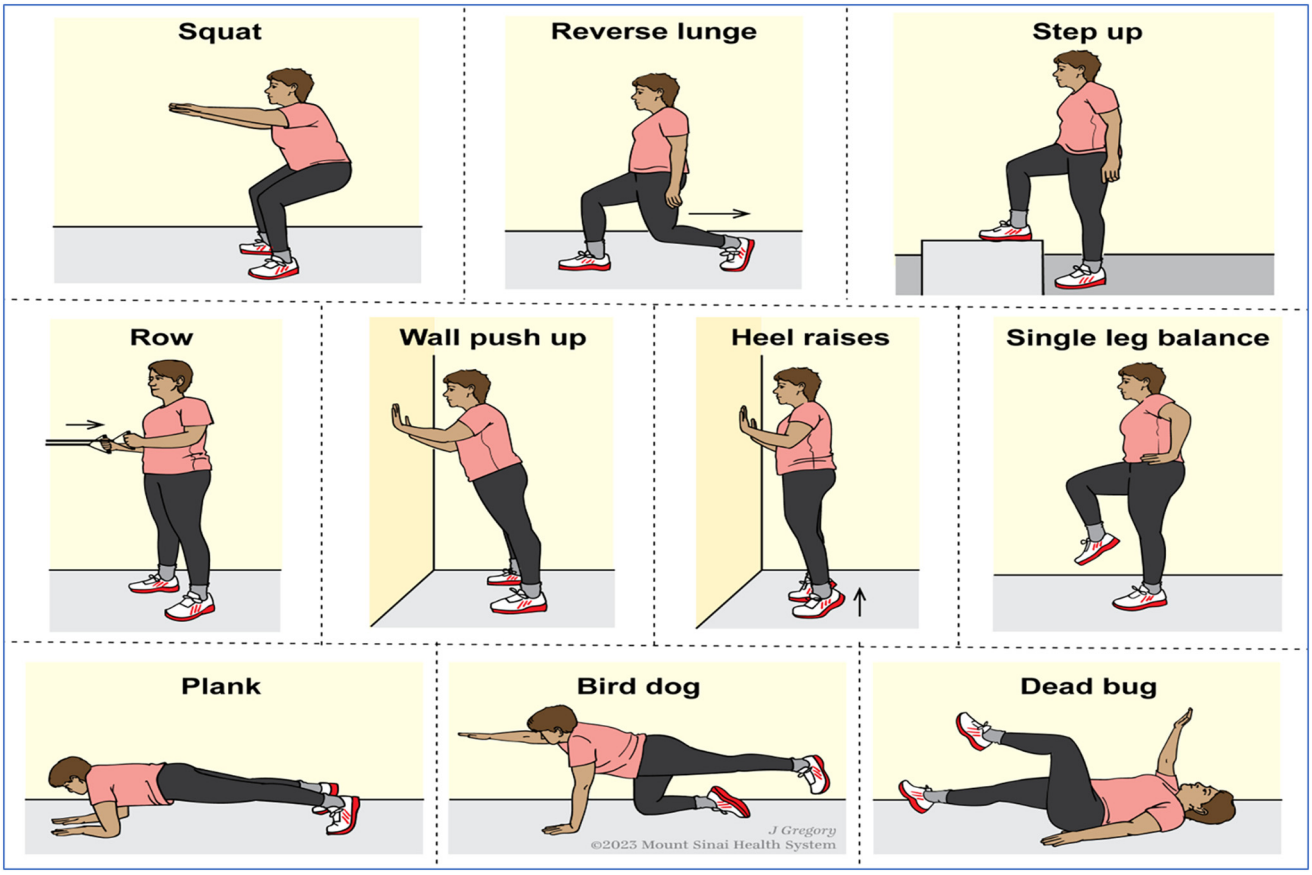

Fig. 9. Illustrative exercises that can be performed without need for specialized machines. (Illustration by Jill Gregory used with permission of © Mount Sinai Health System).

and treat CVD and other chronic illnesses, and to promote optimal health and vitality.

Disclosures

None.

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