Exercise Comes of Age as Medicine for Older Adults

Introduction

The way in which we develop and age, as well as the resilience with which we ward off disease over the lifespan, is strongly linked to our behavior: our dietary intake, physical activity patterns, unsafe pursuits, and internal and external exposure to noxious substances. Genetic factors clearly play an important role in disease accumulation and expression; however, modifications of gene expression (epigenetics) due to intrauterine influences, subsequent lifestyle choices, and other environmental exposures and socio-cultural influences are also capable of substantially changing heritable risk profiles via alterations of gene expression and disease accumulation. Thus, at least partial escape from a genetic predisposition to conditions such as type 2 diabetes, cancer, stroke, coronary artery disease, hypertension, hyperlipidemia, obesity, dementia, depression, osteoporosis, arthritis, and sarcopenia, for example, is possible with the adoption and maintenance of a healthful lifestyle from intrauterine to nonagenarian stages of the life course.

Lifestyle and Chronic Disease

Lifestyle behavior plays a fundamental role in the prevention and treatment of the vast majority of the non-communicable chronic diseases (NCDs) globally. “Sedentary death syndrome” has even been suggested as the appropriate perspective from which to approach the modern epidemics of obesity and related metabolic diseases. Thus, in 2004, the World Health Organization (WHO) adopted the “Global Strategy on Diet, Physical Activity and Health.” This report recognized the unique opportunity to reduce disease burden worldwide by improving diet and promoting physical activity. Despite global efforts to implement this policy, most health care practitioners are poorly trained in the understanding and management of lifestyle behaviors and health care systems are ill-equipped to support this activity. As a result, such approaches are not integrated into usual clinical practice and behavioral change is not uniformly promoted in persons at risk. Indeed, the American College of Sports Medicine (ACSM) began a new initiative in 2007 entitled "Exercise is Medicine" to counteract this syndrome by linking physical activity promotion to physician practice and policy. Fundamentally, as these and other initiatives imply, lifestyle medicine is not ancillary to health care; it is health care. In this paper, the focus will be on the particular role of physical activity as part of an optimal lifestyle for older adults, both fit and frail.
Aging and Physical Activity Patterns

Currently, disparities exist among population groups in habitual physical activity patterns that exaggerate the negative health consequences of a sedentary lifestyle. Virtually unchanged from the landmark 1996 Surgeon General’s Report on Physical Activity and Health, demographic groups still at highest risk for insufficient activity levels are older adults, women, ethnic minorities, those with low income or educational background, and those with disabilities or chronic health conditions. As might be expected, these are the same demographic groups that both bear a large burden of the diseases amenable to prevention and treatment with exercise, and yet often have the least access and opportunity for health promotion efforts related to physical activity.

Previous objectives for middle aged and older adults have primarily focused on physical activities designed to improve cardiorespiratory fitness and/or prolong life. However, it is now recognized that older adults can benefit as much or more from physical activities designed to maintain or improve physical capacity and functional independence. The specific physical fitness components that provide continued physical function as individuals age include muscle strength, cardiovascular and muscular endurance, balance and flexibility. The problems of mobility impairment, falls, arthritis, osteoporotic fractures, and functional status are clearly related in part to muscle strength and mass, characteristics that are amenable to intervention even in frail elders, and thus strengthening activities, while important for all age groups, are particularly important for the oldest old. Additionally, the metabolic benefits of retention and activation of muscle mass are now increasingly recognized as an important facet of the epidemic of age- and obesity-related insulin resistance and type 2 diabetes. Age-related loss of strength, muscle mass (sarcopenia), and bone density, which are most dramatic in women, may be attenuated by strengthening exercises, and improved even in late life with appropriate resistance training.

Unfortunately, US survey and other data indicate that women in general report lower than average adult participation levels for strength training (11% vs. 16%). Additionally, despite the evidence on safety and efficacy in frail elders, the prevalence rate for resistive exercise is even lower among the old (6% at ages 65-74) or the very old (4% above age 75). Individuals in this latter age group, particularly over the age of 85, are primarily women, making an understanding of the risks and benefits of exercise in this population a priority.

Rationale for the Integration of Exercise Prescription into Health Care for Older Adults

The rationale for the integration of a physical activity prescription into geriatric health care is based on four essential concepts. First, there is a great similarity between the physiologic changes which are attributable to disuse (sarcopenia, osteopenia, central and generalized adiposity, low fitness, insulin resistance, etc.) and those that have been typically observed in aging populations, leading to the speculation that the way in which we age may in fact be greatly modulated with attention to activity levels, as summarized in Table 1. Second, chronic diseases increase with age, and exercise has now been shown to be an independent risk factor and/or potential treatment for most of the major causes of morbidity and mortality in industrialized societies (see Table 2), a potential which is currently vastly underutilized. Third, traditional medical interventions don’t typically address disuse syndromes accompanying chronic disease, which may be responsible for much of their associated disability. Exercise is particularly good, and often the only appropriate means to target disuse. Finally, many pathophysiologic features that are central to a disease or its treatment are better addressed by physical activity than by pharmacologic therapy (e.g. the visceral adiposity of metabolic syndrome). Exercise therefore deserves a place in the mainstream of medical care, not as an optional adjunct.

It is clear that the optimum approach to "successful aging” or to health care in the older population cannot ignore the primacy of these issues. In some cases, exercise can be used to avert "age-related” decrements in physiologic function and thereby maximize function and quality of life in older adults. On the other hand, the combination of exercise and sound nutrition, particularly in relation to favorable alterations in body composition, will have numerous important effects on risk factors for chronic disease as well as the disability that accompanies such conditions. In the sections which follow, an overview of the prescription and monitoring of physical activity in older adults is presented, as well as two specific examples of tailored, evidence-based exercise prescription for conditions of great importance to older adults: type 2 diabetes and osteoporosis.

Pre-exercise assessment in older adults

Most adults over 65, despite the presence of chronic diseases and disabilities, are able to undertake and benefit from an exercise prescription that is tailored to their physiological capacities, co-morbidities, and neuropsychological and behavioral needs. The relatively few permanent exclusions to any structured exercise are generally severe irreversible conditions that are obvious because of the nature of the specific exercise prescription under consideration or the risk the exercise would impose upon the health status of the individual. There are even some forms of exercise that even permanently bed-bound patients, or those with severe behavioral problems may engage in. For some older adults, such as those with critical aortic stenosis, cardiac or peripheral vascular ischemia at rest, or an inoperable aortic aneurysm for example, any exercise that significantly elevates cardiac workload or blood pressure is considered high risk, and therefore not recommended. Relatively few older adults (even those in long-term care) would
be excluded from all physical activity prescription based on medical diagnoses, outside of those with severe forms of dementia or rapidly terminal illness.

Notably, the vast majority of chronic illnesses are indications for, rather than contraindications to, regular exercise. For example, if an older adult with osteoarthritis, chronic renal failure on dialysis, peripheral vascular disease, diabetes and depression is not exercising, their medical management should be seen as sub-optimal, as regular exercise is in fact additive to the benefits of usual medical care in these, and most other chronic conditions. Therefore, screening an older adult for exercise should be seen as an opportunity to “screen in” sedentary older adults who have exercise-responsive diseases, rather than primarily as a task of “screening out” those few older adults with conditions which absolutely preclude exercise of any sort. Major chronic diseases for which there is substantive evidence that exercise is beneficial as a preventive measure or as part of treatment or rehabilitation management plans are shown in Table 2.

Exercise Prescription in Older Adults

It is quite likely that after initial screening, many barriers and difficulties with adoption and adherence will be identified in the typical sedentary older individual. Therefore, it becomes important to know how to deliver the prescription in logical stages that are palatable and feasible, and have some likelihood of successful implementation. Current position stands generally recommend a multi-modal exercise prescription including aerobic, strengthening, balance, and flexibility training, via a combination of structured and incidental (lifestyle-integrated) activities. However, it is usually best to start with only one mode of exercise and let the individual get used to the new routine of exercise before adding other components, or optimal adherence and adaptation may be compromised. This approach obviously requires attention to risk factors, medical history, physical exam findings, and personal preferences, in order to prioritize prescriptive elements, and will be different for each individual. However, there are a few generalizations that can be made, as noted below:

- If significant deficits in muscle strength or balance are identified, these should be addressed prior to the initiation of aerobic training. Prescribing weight bearing aerobic training in the absence of sufficient balance or strength is likely to result in knee pain, fear of falling, falls, and limited ability to progress aerobically, and is not recommended. Similarly, in long term care, attempting to ambulate those who cannot lift their body weight out of a chair or maintain standing balance is a sub-optimal approach.

- In some cases, a chronic health condition may benefit equally from resistance or aerobic training (as in the treatment of depression for example) but the decision is made based on ability to tolerate one form of exercise over another. Severe osteoarthritis of the knee, recurrent falls, and a low threshold for ischemia may make resistance training safer than aerobic training as an antidepressant treatment in this case.

- Preference for group vs. individual exercise, structured vs. lifestyle physical activity, level of supervision desired, and attraction or aversion to specific modalities of exercise must be considered to optimize behavioral change and long-term adherence.

Monitoring the Benefits of Exercise

Most health outcomes appear to be related to the accumulated volume and intensity of exercise, and so monitoring compliance will theoretically provide evidence that the desired beneficial adaptations are occurring. However, there may be benefit also in monitoring the improvements in cardiovascular fitness from training, as aerobic capacity itself has an even stronger relationship to mortality than level of physical activity. Documenting improvements in fitness or function may have a reinforcing effect on long-term behavioral adaptations as well.

Type 2 diabetes: An example of the critical role of exercise in disease prevention and treatment

Although all of the conditions listed in Table 2 are important for older adults, there is an especially urgent need for better strategies to address the global epidemic of type 2 diabetes. This condition may be conceptualized as a lifestyle-related disorder, linked to sedentary behavior and visceral obesity in genetically susceptible individuals. Visceral obesity carries with it many more health problems than general obesity and, along with sedentary behavior, links insulin resistance, the metabolic syndrome, systemic inflammation, type 2 diabetes and the vastly elevated risk of cardiovascular morbidity and mortality in this cohort. Visceral adipose tissue produces inflammatory “adipokines”, which appear to be causally linked to insulin resistance in muscles, liver, and endothelial cells. Coupled with the sarcopenia of aging and inactivity (which limits the major site and stimulus for peripheral glucose uptake and storage), these body composition and behavioral changes lead directly to the metabolic derangements characterizing this syndrome (see Figure 2).

Current treatment is inadequate

Current treatment is usually hypocaloric diet, medications, and aerobic exercise recommendation. However, current pharmacological treatment of type 2 diabetes focuses on management of the resulting hyperglycemia, hypertension, dyslipidemia and atherosclerosis, yet does not address the underlying causes leading to insulin resistance: visceral obesity and physical inactivity. Paradoxically, insulin and some oral hypoglycemics cause significant weight gain. Additionally, older obese adults find weight loss diets are notoriously difficult to
### Table 1: Selected Physiological Benefits of Aerobic and Resistance Training in Older Adults

<table>
<thead>
<tr>
<th>Physiologic Adaptations</th>
<th>Aerobic Training Benefit</th>
<th>Resistance Training Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased bone density, bone mass, and structural integrity</td>
<td>X</td>
<td>XX</td>
</tr>
<tr>
<td>Decreased total body and visceral adipose tissue, decreased intramuscular and hepatic lipid accumulation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Increased muscle mass, strength, power, endurance</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Decreased fibrinogen levels</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Decreased sympathetic and hormonal response to exercise</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Decreased LDL, increased HDL levels, increased fat oxidation</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Improved cognitive function</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Increased hippocampal volume of brain</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Decreased heart rate/BP/perceived exertion response to sub maximal exercise; increased maximal aerobic capacity</td>
<td>XX</td>
<td>X</td>
</tr>
<tr>
<td>Increased oxygen extraction by skeletal muscle, capillary density</td>
<td>XX</td>
<td>X</td>
</tr>
<tr>
<td>Increased heart rate variability</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Increased neural reaction time</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Decreased resting heart rate and blood pressure</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Increased GLUT-4 receptors in skeletal muscle, insulin sensitivity, glycogen storage, decreased fasting glucose and insulin levels, decreased post-prandial hyperglycemia</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Decreased central and peripheral arterial stiffness</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Increased stroke volume during exercise*</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Increased cardiac contractility during exercise*</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Decreased systemic inflammation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Improved endothelial cell function, vascular reactivity</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Increased energy expenditure (total, resting*, exercise-related)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Increased oxidative enzyme capacity in skeletal muscle</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Increased mitochondrial volume density in skeletal muscle, mitochondrial function</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Improved baroreceptor function, decreased orthostasis in response to stressors</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Increased blood volume and hematocrit</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Improved balance</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Improved gait speed and stability</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Decreased sleep latency, increased sleep quality</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Key and Notes**

* Observed only in older endurance-trained men thus far.

** Data on resting energy expenditure is mixed; PRT has been shown to lessen/offset the decline in REE seen with hypocaloric weight loss diets.

X Indicates that the physiological adaptation is seen with the mode of exercise indicated in the majority of well-conducted studies to date. Some adaptations have not been studied sufficiently after PRT to draw firm conclusions (e.g., arterial compliance).

XX Indicates that the benefit is generally larger with the specified mode of training.
### Table 2: Utility of Exercise in Clinical Practice

<table>
<thead>
<tr>
<th>Disease Prevention</th>
<th>Disease Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthritis (prevention of obesity and sarcopenia)</td>
<td>Arthritis</td>
</tr>
<tr>
<td>Cancer (breast, colon, endometrial, prostate)</td>
<td>Cancer (treatment of cancer cachexia, sarcopenia, depression)</td>
</tr>
<tr>
<td>Chronic renal failure (via prevention of hypertension and diabetes)</td>
<td>Chronic renal failure, treatment of co-morbidities during dialysis and post organ transplant</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>Coronary artery disease</td>
</tr>
<tr>
<td>Congestive heart failure (via prevention of CAD and hypertension)</td>
<td>Congestive heart failure, treatment post organ transplant</td>
</tr>
<tr>
<td>Dementia, mild cognitive impairment</td>
<td>Dementia, mild cognitive impairment</td>
</tr>
<tr>
<td>Depression</td>
<td>Depression</td>
</tr>
<tr>
<td>Disability</td>
<td>Disability</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>Hyperlipidemia</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Hypertension</td>
</tr>
<tr>
<td>Impotence (via prevention of diabetes and peripheral vascular disease)</td>
<td></td>
</tr>
<tr>
<td>Insomnia (via prevention of obesity leading to obstructive sleep apnea and prevention of depression)</td>
<td>Insomnia</td>
</tr>
<tr>
<td>Obesity, Visceral obesity</td>
<td>Obesity, Visceral obesity</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>Osteoporosis, fracture rehabilitation</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>Peripheral vascular disease</td>
</tr>
<tr>
<td>Parkinson’s disease (treatment of accompanying sarcopenia and frailty)</td>
<td></td>
</tr>
<tr>
<td>Recurrent falls</td>
<td>Recurrent falls</td>
</tr>
<tr>
<td>Stroke</td>
<td>Stroke</td>
</tr>
<tr>
<td>Type 2 diabetes, Metabolic syndrome</td>
<td>Type 2 diabetes, Metabolic syndrome</td>
</tr>
<tr>
<td>Type 1 diabetes</td>
<td></td>
</tr>
</tbody>
</table>
adhere to, but if they do lose weight such dieting may cause exacerbation of losses of muscle tissue due to aging, inactivity, and systemic inflammation. Finally, volumes and intensities of aerobic exercise shown to improve glucose homeostasis in clinical trials are often impossible for typical older obese patients with diabetes to manage due to osteoarthritis, gait and balance disorders, peripheral vascular disease, neuropathy and other co-morbidities. Thus, failure to realize clinical improvements due to repeated unsuccessful attempts at weight loss through diet or unrealistic aerobic exercise prescriptions sets up a vicious cycle of failure and lowered motivation to change behavior, accentuation of poor self-esteem and worsening of depressive symptoms. This explains the heavy reliance on pharmacological management, despite this being a “lifestyle” disorder linked to physical inactivity and diet.

**What is the role of weight lifting exercise in type 2 diabetes?**

Although aerobic exercise is usually thought of as the primary exercise modality important in diabetes management, progressive resistance training (PRT), or weight lifting exercise, offers a radically different approach to the treatment of type 2 diabetes and metabolic syndrome which has particular relevance to the older adult. PRT is an anabolic form of exercise, differing substantially from aerobic exercise in its ability to induce muscle hypertrophy and associated metabolic and functional changes. It improves insulin sensitivity, glucose homeostasis, as well as blood pressure, dyslipidaemia, markers of inflammation and catabolism and visceral obesity, thus addressing all of the components of metabolic syndrome in type 2 diabetes (see Figure 2). PRT has also been shown in randomized trials to improve aerobic capacity, osteoarthritis pain and disability, depression, functional status, gait and balance impairments, claudication, bone density and insomnia, thus addressing the spectrum of associated clinical disorders in adults with type 2 diabetes, particularly in older adults. Notably, high intensity PRT is feasible even when robust aerobic exercise is impossible due to osteoarthritis or peripheral vascular disease, making it particularly suitable for the obese elderly individual with diabetes. It is less likely to provoke cardiac ischemia or dyspnea than is aerobic exercise in those with coronary disease, heart failure or chronic lung disease.

Importantly and uniquely, PRT offsets the loss of lean tissue (muscle and bone) that would otherwise accompany weight loss diets typically prescribed for overweight adults, thus minimizing the potential for weight cycling related to lowered basal metabolic rate. This unique constellation of benefits: metabolic, cardiovascular, body composition, psychological, and functional, provided by this anabolic mode of exercise makes it particularly appropriate as a central component of the lifestyle modification management of type 2 diabetes and metabolic syndrome.

**How to prescribe weight lifting exercise for diabetes**

The benefits of PRT are related to both acute alterations in insulin sensitivity as well as chronic body composition adaptations (increased muscle and decreased visceral, hepatic, intramuscular, and whole body fat depot). As the acute effect is most prominent in the 48 hours after an exercise bout, it is recommended that PRT be undertaken three days per week for metabolic control (with at least one day of rest between training for muscle recovery and hypertrophy). Engagement of most major muscle groups (eight to ten different weightlifting exercises) is best for metabolic and functional benefits, and should take about 30 to 45 minutes to complete two to three sets of eight repetitions. Most successful trials have used moderate-to-high intensity training (lifting about 60-80% of the maximum weight possible for a given exercise, or an 8-to-10 repetition maximum, then progressively increasing the load as strength is gained). This is the same PRT prescription that benefits the other co-morbidities prevalent in type 2 diabetes (see Figure 2) and in older adults for other chronic conditions (see Table 2), thus providing a single, economical exercise foundation for such individuals. However, aerobic exercise provides benefits complementary and in some cases superior to PRT, such as improved cardiovascular fitness, peripheral vascular disease symptoms, and other metabolic functions such as fat oxidation and reduced inflammation. Thus, a combination of PRT and aerobic exercise in older adults, as recommended by the American College of Sports Medicine and others, is theoretically optimal for disease prevention, and combined aerobic and resistance training is superior for changes in HbA1c, but not for any other metabolic, cardiovascular, musculoskeletal, or body composition outcomes compared to uni-modal exercise, despite double the volume of exercise.

The most difficult part of this prescription currently is the insufficient availability of suitable facilities and qualified trainers to oversee this clinical cohort, in whom both physical and psychological barriers to participation are numerous, and result in low rates of exercise adoption and adherence to any modality of exercise. Unsupervised home-based PRT has not been as successful as supervised training in gyms or laboratories for diabetes treatment, most likely due to a reduced volume, intensity, and progression of PRT at home. Development of better behavioral change strategies uniquely designed to understand and promote sustained adherence to PRT are critical to the translation of the highly successful clinical trials to the wider community of adults with type 2 diabetes. Thus, the rationale and specifics of the role of PRT in diabetes can be summarized as follows:

- Volumes and intensity of aerobic exercise shown to improve hyperglycemia are often impossible for typical older obese patients with cardiovascular disease and arthritis to manage.
• PRT is anabolic and improves insulin sensitivity, glucose homeostasis, as well as blood pressure, dyslipidemia, markers of inflammation and catabolism and visceral obesity.

• PRT improves aerobic capacity, osteoarthritis, depression, function, gait and balance impairments, claudication, bone density and insomnia, thus maximizing the economy of this prescription in typical older adults with multiple co-morbidities.

• It is recommended that PRT be undertaken 3 days per week, with 30 to 45 minutes taken to complete two to three sets of eight repetitions, under supervision initially for maximal efficacy and safety, although home-based exercise is possible. Although 2 days per week minimum has been recommended by ACSM, 3 days per week produces superior strength outcomes and is the dosage used in most successful clinical trials of cardiovascular disease and type 2 diabetes.

What does physical activity have to do with fracture risk in older adults?

Epidemiological studies suggest that habitual exercise participation is associated with a reduction in osteoporotic fracture risk of up to 50% in older men and women. Currently, randomized controlled trials have only examined the efficacy of exercise in preventing spinal fractures, and this remains an important gap in our knowledge. However, what optimal physical activity participation clearly can do is maximize the attainment of peak bone mass and attenuate age- and menopause-related bone loss, as well as improve the risk factor profile associated with osteoporotic fracture in older adults (such as low muscle mass and strength, poor gait and balance, and depression).

Typical Patterns of Bone Loss with Age

Bone mass begins to decrease well before the menopause in women (as early as the 20’s in the femur of sedentary women), and accelerates in the peri-menopausal years, with continued declines into late old age. Similar patterns are seen in men, without the acceleration related to loss of ovarian function seen in women. As with losses of muscle tissue (sarcopenia), many genetic, lifestyle, nutritional, and disease and medication-related factors enter into the prediction of bone health at a given age. However, a wealth of epidemiologic and experimental data provide evidence for a strong relationship between physical activity and bone health at all ages. Mechanical loading of the skeleton generally leads to favorable site-specific changes in bone density, morphology, or strength, whereas unloading (in the form of bed rest, immobilization, casting, spinal cord injury, or space travel) produces rapid and sometimes dramatic resorption of bone, mimicking many years of “aging”, and increased susceptibility to fracture.

Consistent with such bone density findings, hip fracture incidence has been observed to be as much as 30-50% lower in older adults with a history of higher levels of physical activity in daily life, compared to age-matched, less active individuals. Overall, cross-sectional and prospective cohort data support a relationship between lifetime physical activity patterns and preservation of bone density into old age, as well as a protective effect for hip, humerus and vertebral fractures in both men and women. These reduced risks for fracture remain after adjustment for most major known risk factors for osteoporosis, and are not completely accounted for by alterations in bone density, muscle strength, or fall rates.

What kind of exercise should be used to treat osteoporosis?

Moderate- to high-intensity weight-bearing aerobic exercise, high-intensity progressive resistance training and high-impact loading (such as jumping) increase BMD (primarily in the spine) by an average of 1% in pre- and postmenopausal women, whereas exercise such as low-moderate intensity walking alone has inconsistent effects on preservation of bone density. By contrast, significant benefits of exercise for the femoral neck are not proven. More robust exercise interventions appear to produce greater effects. Inclusion of weight-lifting and balance-training exercises should provide the widest range of benefits relevant to fracture protection, as well as reducing muscle weakness, falls risk and depression, and increasing muscle mass and mobility. Whether these benefits translate into hip fracture reduction is currently unknown, but it is reasonable to use exercise for risk factor modification pending completion of such studies.

Although there are still many unanswered questions with regard to the optimal prescription of exercise for bone health, and in particular its ultimate efficacy for hip fracture prevention, there is evidence that bone responds positively to novel mechanical forces, with rapid, short bursts of high intensity loading more effective than sustained, low intensity loading. For example, jumping is more stimulating to bone cells than sustained, low impact activity such as walking.

Although weight-bearing aerobic exercise, high impact training, and resistance training have all been shown to maintain or augment bone density in this stage of life, resistance training has the added benefit of increasing muscle mass and strength, as well as balance. This combination of effects on body composition and muscle function is a direct antidote to age-associated changes in these domains, and offers potential benefit for many health conditions in addition to osteoporosis. Aerobic exercise does not increase muscle mass and strength, and does not improve balance, and is therefore less comprehensive in its effects on the multiple risk factors for osteoporotic fracture. Additionally, there is no evidence in young women to support the isolated use of aerobic training that does not involve high impact forces as a means to
maintain or augment femoral bone density, whereas programs
that include resistance training and/or high impact training have
been shown to benefit the skeleton at this clinically vital site.

Therefore, the most economical prescription with the broadest
benefits for body composition and bone health as well as
neuromuscular function would appear to be resistance training as
the exercise modality. Adding high impact forces/movements may
further enhance benefits for the femoral neck or trochanter, lower
extremity muscle power, and dynamic balance, but no direct
comparisons of these 2 modalities are available. Rest periods
between sets of weight-lifting exercise may be used to complete
jumps if feasible (depending on the presence or absence of
previous injuries or osteoarthritis of the knees and hips). Such a
routine incorporates resistance training and high impact loading
in one session without extending the time required, an economical
prescription for busy older adults. Examples of the use of varied
exercise prescriptive elements for the prevention and treatment of
osteoporosis and osteoporotic fracture are presented in Table 3.

In summary, type 2 diabetes and osteoporosis represent complex
disease processes which are prevalent and morbid in older adults,
and for which there is ample evidence that physical activity should
be centrally positioned within the holistic approach to these
problems. The need for a full integration of exercise and medicine
is obvious, but current training and practice of clinicians who treat
these diseases has not yet caught up to the evidence available.

Conclusion

“To array a man’s will against his sickness is the supreme art of medicine.”

Henry Ward Beecher
Theologian, preacher, abolitionist, women’s suffragist
(1813–1887)

It has been 120 years since Beecher’s profound acknowledgement
of both the power of the individual to battle illness, as well as
the role of the health care practitioner to summon that power
when needed. These two forces, combined, have been the subject
of prolific investigation in the intervening years, spanning
such topics as theoretical models of behavioral change, self-
management of chronic disease, improvement of doctor-patient
relationships, the role of social support, optimism, and positive
affect on health and well-being, and lifestyle modification for
the prevention and treatment of chronic disease. Most recently, gene-
lifestyle interaction, in which physiological adaptation to physical
activity, diet, or other behaviors is linked to genomic variation,
and conversely, diet or exercise results in epigenetic modification
altering gene expression, has sparked enormous interest. Never
before have we had so much indication that our behavior and our
will are integral to our well being and resistance to disease.

Despite this wealth of knowledge, exercise as medicine remains
at the periphery of medical education, clinical practice, and health
care policy, particularly as it applies to older adults. Few health
care professionals are sufficiently trained to understand or
implement lifestyle modification; health services and clinical
programs are not designed to deliver it in a manner that is
robust, sustainable, or evidence-based, and insurance providers/
Medicare do not generally cover provision of lifestyle programs,
except for time-limited diagnostic indications. If we had a pill
that could cut the risk of heart disease in half, surely it would
be funded by our government, and promoted by all health care
practitioners starting in early life. We have that pill, its name
is exercise. Similarly, lifestyle modification (diet and exercise)
has now been shown in diabetes prevention trials to reduce
incident type 2 diabetes in high-risk adults by 30-70% in the US,
China, Finland, India, Japan, Italy, and Sweden—much more
effectively than metformin. Yet it is metformin that is available
and reimbursable in most countries for this purpose, and the
translation of the randomized trial evidence into primary care is
far from accomplished, accepted, or proven as cost-effective.
The gap between knowledge and effective health promotion by
clinicians and government policy is nowhere more evident than in
these examples.

Exercise is integral to the prevention, treatment, and rehabilitation
strategies necessary for the care of older adults. Exercise should
be prescribed, as is all other medical treatment, with consideration of
its unique risks and benefits, knowledge of appropriate modality
and dose (intensity, frequency, volume), monitoring for drug
interactions, benefits and adverse events, and utilization of the
strongest possible behavioral medicine techniques known to
optimize adoption and adherence. There is no age above which
physical activity ceases to have benefits across a wide range of
diseases and disabilities. Sedentariness is a lethal condition;
physical activity is the antidote, and health care practitioners
should be well-educated leaders and role models in the effort to
enhance functional independence, psychological well-being, and
quality of life through promotion of exercise for the aged, both fit
and frail. Importantly, frailty is not a contraindication to exercise.
It is, by contrast, one of the most important reasons to prescribe it.
### Exercise Modality

<table>
<thead>
<tr>
<th>Exercise Modality</th>
<th>Standard or Optimal Mode</th>
<th>Modification for Arthritis</th>
<th>Modification for Frailty/Neuromuscular Impairment</th>
<th>Modification for Cardiovascular/Pulmonary Disease</th>
</tr>
</thead>
</table>
| **Progressive Resistance**        | • 8-10 exercises for major muscle groups, including muscles attaching to greater trochanter and vertebral bodies, as well as muscles important for gait and balance (hip abductors, ankles)  
• Include novel planes of movement, free weights, standing postures if possible  
• High intensity (approximately 80% of peak capacity, progressed continuously) | • Provide exacting attention to form to prevent injuries  
• May need to limit range to pain-free motion, provide good back support, adjust machines or free weights to accommodate joint deformities or restrictions  
• Intensity may need to be individualized for some exercises  
• May need to medicate for pain prior to exercise | • Usually little modification needed  
• May need to alter certain exercises for neurological impairment  
• May need to perform exercises in seated rather than standing positions due to fatigue or poor balance  
• Supervision usually needs to be more intensive for safety and progression | • Usually no modification needed  
• If angina or ischemia is provoked by exercise, keep intensity below the level at which this occurs  
• Avoid breath holding, Valsalva maneuver, sustained isometric contractions or tight handgrip during weightlifting |
| **Aerobic Training**              | • Moderate to high intensity  
• Weight-bearing  
• High ground reaction forces (jogging, stepping, jump rope, etc.) | • May need to reduce or eliminate weight bearing or high impact component: substitute brisk walking, stair climbing for jogging, step aerobics | • May need to substitute seated exercises if weakness or poor balance prevents standing postures  
• May need to begin with low-moderate intensity level and short sessions until improved | • Keep training intensity below the level that causes ischemia or severe dyspnea  
• Walk or exercise beyond the onset of claudication if possible (1-2 minutes); then rest and repeat  
• Avoid breath holding, Valsalva maneuver, sustained isometric contractions or tight handgrip during | |
| **High impact exercise**         | • Jumping, stepping off boxes, jump rope  
• Progressively increase height of jumps or boxes, hop on one leg | • May need to reduce or eliminate high ground reaction forces (Heel drops instead of jumps)  
• Substitute power training (rapid concentric muscle contraction against moderate to high load on weight-lifting machine) to produce rapid onset of high muscle contraction forces as in take off of jump, but with no impact | • Start with heel drops instead of jumps  
• Perform exercises under supervision and while holding onto a support rail initially  
• Gradually reduce hand support as tolerated | • Keep training intensity below the level that causes ischemia or severe dyspnea | |
| **Balance Training**             | • Combine progressively more difficult static and dynamic postures  
• Reduce base of support  
• Perturb center of mass  
• Withdraw vision  
• Increase compliance of standing surface (decrease proprioception) by using pads, mattress, pillows to stand on  
• Incorporate postures from yoga and t’ai chi which emphasize the above principles | • May not be able to place full body weight on osteoarthritic joints- use less painful leg to perform one-legged postures, assist weight bearing with use of cane  
• Keep sessions short to avoid pain from prolonged weight bearing  
• Reduce angle of flexion at knee during t’ai chi movements | • Perform exercises under supervision and while holding onto a support rail initially  
• Gradually reduce hand support as tolerated | • Usually none |
References

1. Balluz LS, Okoro CA, Mokdad A. Association between selected unhealthy lifestyle factors, body mass index, and chronic health conditions among individuals 50 years of age or older, by race/ethnicity. Ethn Dis 2008;18:450-7.


Epigenetics refers to the modification of the genome (by lifestyle or other environmental exposures) to alter gene expression and related disease risk. Ecological factors are environmental and cultural/societal factors outside of the individual, which may interact with intrapersonal factors (personality, lifestyle, etc.) to influence health status. Behavioural constructs are intrapersonal factors, and may include self-efficacy, self-esteem, motivation, decisional balance, and other character states and traits that can influence behaviour, including exercise behaviour.
Figure 2: Mechanism and potential benefits of progressive resistance training in type 2 diabetes

CRP = C-reactive protein  
IGF-1 = Insulin-like Growth Factor 1  
IL = Interleukin  
OA = Osteoarthritis  
TNF = Tumour necrosis factor