Original Article

# Benefits of exercise and dietary measures to optimize shifts in body composition with age

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Ageing is associated with changes in body composition, including an increase and redistribution of adipose tissue and a decrease in muscle and bone mass, beginning as early as the fourth decade of life. These changes have significant implications for the health and functioning of the individual because of their associations with chronic disease expression and severity, as well as geriatric syndromes such as mobility impairment, falls, frailty and functional decline. Therefore, understanding the preventive and therapeutic options for optimizing body composition in old age is central to the care of patients in mid-life and beyond. Pharmacological interventions are currently available for maintaining or improving bone mass, and much current interest is focused on anabolic agents that will preserve or restore muscle mass, as well as those that can potentially limit adipose tissue deposition. However, in this brief review, non-pharmacological modulation of body composition through appropriate dietary intake and physical activity patterns, will be discussed. There is sufficient evidence currently to suggest that a substantial portion of what have been considered 'age-related' changes in muscle, fat and bone are in fact related either to excess energy consumption, decreased energy expenditure in physical activity, or both factors in combination. In addition, selective underconsumption of certain macro- or micronutrients contributes to losses of muscle and bone mass. Each of the three compartments will be considered in turn, with recommendations for optimizing the size of these body tissue stores in early adulthood, and minimizing undesirable changes typically seen in middle and old age.

**Key words: Ageing, obesity, osteopenia, physical activity.**

## Introduction

There are many reasons to integrate exercise and nutrition into the conceptual model of healthy ageing, but clearly one of the most potent pathways from physical activity to health status involves the modulation of body composition by habitual exercise patterns or dietary intake.[1,2] Body composition is the division of the body mass into its component parts, along the lines of physical, chemical or other properties of the tissues.[3] Some of the most common methods divide the body into fat and fat-free (or lean) mass, using various techniques, such as hydrostatic weighing, isotopic measurements of total body water, dual energy X-ray absorptiometry,[4] computed tomography (CT),[5] or elemental analysis of total body potassium, carbon, nitrogen and calcium, for example.[6–9] Lean body mass includes muscle, bone and visceral organs. Adipose tissue may be divided into its subcutaneous, truncal, appendicular and visceral components, if regional imaging techniques such as magnetic resonance imaging or CT scanning are utilized.[10] Because ageing is associated with decreased energy requirements, and increased protein requirements,[11] for the reasons shown in Table 1, there is a potential for body composition changes and adverse consequences to occur over time. In addition, decreases in energy expenditure in physical activities (including recreational, work-related and household tasks), as well as changes in the types and intensities of activities undertaken, may exacerbate body composition changes associated with biological ageing and nutritional factors.

The typical patterns of change in body compartments seen in 'usual aging' are outlined in Table 2. The extent to which these changes occur in an individual depend upon a combination of genetic, lifestyle and disease-related factors, which are all interrelated.[12,13] For example, if energy intake is restricted with ageing due to decreased requirements, micronutrient deficiencies (such as calcium) may arise unless nutrient density is increased to compensate for the reduced volume of food. If energy intake is not appropriately matched to decreased needs, than obesity may result. If protein requirements are not met,[14] than muscle wasting may be accelerated. The level of resistive exercise and loading applied to bone will moderate the age-related losses in these

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**Table 1.** Age-related changes in nutritional requirements related to body composition

| | |
|---|---|
| Decreased energy requirement | Muscle mass decreases, lowering basal metabolic rate, fewer calories are used in physical activity, thermic effect of meal reduced as food intake is decreased, potential for micronutrient deficiencies, which exacerbate body composition changes (vitamin D, calcium, protein) due to low energy intake. |
| Increased protein requirement | Decreased protein synthesis rate, decreased nitrogen retention in the face of low energy intakes. |

**Table 2.** Age-related changes in body compartments

| | |
|---|---|
| Bone | Decrease in total body calcium, decreased bone density, increased bone fragility. |
| Muscle | Decrease in total body potassium, decrease in total body water, decreased muscle mass and per cent of body mass, decreased muscle quality, increased connective tissue volume, decrease in total body nitrogen and protein content. |
| Fat | Increased total body fat mass and per cent of body mass, increase in central and visceral fat deposition. |

compartments, even in the face of inadequate nutrient intake.[15,16] All of these nutritional and body composition changes will have a negative impact on metabolic, cardiovascular and musculoskeletal function,[17–19] even in the absence of overt disease; therefore, it is imperative to anticipate and optimize lifestyle choices that can counteract the negative effects of ageing and/or disease on body composition.

**Relationship of body composition to chronic disease**

In the conceptual model used for the present discussion, chronic diseases and geriatric syndromes can be categorized, which are potentially modifiable by exercise or dietary intake, if an underlying derangement in body composition is addressed. For example, a stabilization or increase in bone mass is achievable by either resistive,[20–23] or weight-bearing aerobic exercise,[24–29] as well as increased intake of vitamin D and calcium.[30] Such effects on bone density are important for both prevention and treatment of osteoporosis and related fractures and disability. Decreases in both total adipose tissue accumulation and abdominal (visceral) deposition are achievable by both aerobic,[31–33] and resistive training,[34–36] with significant changes in total body fat usually only in conjunction with an energy-restricted diet.[10,37,38] This prevention of excess adiposity is both protective and therapeutic for many common chronic diseases, offering significant risk reduction in the case of osteoarthritis, cardiovascular disease, gall bladder disease, type II diabetes, breast, colon and endometrial cancer, hypertension, stroke, and vascular impotence, for example.[39–44] Although generalized obesity is associated with excess mortality, cardiovascular disease, osteoarthritis, mobility impairment, and disability, it is predominantly excess visceral fat that is associated with the derangements of dyslipidemia, elevated fibrinogen, hyperinsulinemia, glucose intolerance or diabetes, and vascular insulin resistance and hypertension.

Although less of a problem than obesity in terms of prevalence, energy malnutrition may result in losses of adipose tissue severe enough to impair thermal regulation, reduce padding over the greater trochanter and thereby increase risk of hip fracture, or alter fat-soluble vitamin or drug metabolism and oestrogen production.

An increase in muscle mass, in contrast to changes in fat and bone, is only achievable to a significant degree with progressive resistance training or generalized weight gain from extra energy and protein consumption,[45–50] and has a potential role in prevention for diabetes,[51–54] functional dependency,[55–58] and falls and fractures,[59–64] as well as being important in the treatment of chronic diseases and disabilities,[65] which are accompanied by disuse, catabolism, and sarcopenia. For some diseases, like type II diabetes mellitus, there are potential advantages to both minimizing fat tissue as well as maximizing muscle tissue, since these compartments have opposite and likely independent effects on insulin resistance in the elderly.[10]

**Adipose tissue mass and distribution**

Recommendations for prevention and treatment of excess adipose tissue stores are outlined in Tables 3 and 4. The primary modality for the prevention of obesity is the maintenance of energy balance (intake equal to expenditure), which requires attention to both dietary intake patterns and physical activity levels beginning perhaps as early as infancy. In developed countries, where access to energy-dense food sources is not restricted for the majority of the population, and technological advancements limit opportunities for exercise in daily life and provide sedentary substitutes for recreation (e.g. television, video games), maintaining this balance becomes more and more difficult with time, leading to a modern epidemic of obesity and obesity-related diseases.[66]

Dietary recommendations for the prevention or treatment of obesity must include an energy deficit for the obese, or energy balance for the non-obese. This usually involves decreasing the fat and saturated fat content of the diet, to produce a less energy-dense diet. Ratios of carbohydrate : protein : fat joules of approximately 60% : 15% : 25% are generally desirable. Although short-term consumption of diets with lower than 25% fat is possible and effective, hunger is usually significant on such diets, and they are difficult to sustain over time, leading to relapse, weight-cycling and frustration on the part of the dieter. Frequent weight-cycling has been shown to lead to decreases in lean body mass (muscle and bone) and

**Table 3.** Dietary recommendations for optimal body composition in older adults

| Nutritional recommendations | Adipose tissue mass and visceral deposition | Muscle mass and strength | Bone mass and density; fracture risk |
|---|---|---|---|
| Total energy | Limit to match energy expenditure (approximately 120 kJ/kg per day); 2000 kJ per day deficit if weight loss desired | Match energy expenditure or increase if underweight or frail | Match energy expenditure or increase if underweight or frail |
| Total fat | Limit to less than 30% of total joules | Increase if underweight or frail | Increase if underweight or frail |
| Saturated fat | Limit to less than 10% of total joules | NA | NA |
| Protein | Maintain at approximately 12–15% of total joules; 0.8–1.2 g/kg per day | Maintain at approximately 12–15% of total calories; 0.8–1.2 g/kg per day; increase if undernourished or catabolic | Maintain at approximately 12–15% of total calories; 0.8–1.2 g/kg per day; increase if undernourished, or recent hip fracture or catabolism |
| Calcium | NA | NA | 1200 mg/day |
| Vitamin D | NA | 400–600 IU/day | 400–800 IU/day |
| Alcohol | NA | Limit to 2 drinks per day or less | Limit to 2 drinks per day or less |
| Cola drinks | Use sugar-free if overweight | NA | Limit to less than 5 per day |

NA, not applicable.

**Table 4.** Exercise recommendations for body composition in older adults

| Exercise recommendations | Adipose tissue mass and visceral deposition | Muscle mass and strength | Bone mass and density; fracture risk |
|---|---|---|---|
| Modality | Aerobic or resistance training | Resistance training | Resistance training plus high impact activities (jumping using weighted vest during exercise) if tolerated† |
| Frequency | 3–7 days/week | 3 days/week | 3 days/week |
| Dose | 30–50 min/session | 2–3 sets of 8–10 repetitions of 6–8 muscle groups | 2–3 sets of 8–10 repetitions of 6–8 muscle groups; 50 jumps per session |
| Intensity | 60–75% of maximal exercise capacity ($VO_{2max}$ or maximal heart rate) or 13–14 on the Borg Scale of perceived exertion | 70–80% of maximal strength (one repetition maximum) | 70–80% of maximal strength (one repetition maximum); 5–10% of body weight in vest |

†Aerobic activities have a less robust effect on bone than resistive activities; if used, aerobic activities should be weight-bearing forms of exercise (e.g. walking rather than swimming or cycling).

decreased basal metabolic rate, making subsequent attempts at weight loss through energy restriction even more difficult. In addition, weight-cycling aggravates the typical age-related losses of lean body mass and is thus particularly undesirable for peri- or postmenopausal women.

In general, energy from fat sources is replaced by energy from carbohydrate sources (fruits, vegetables, grains) in moderate energy-restricted diets, thus boosting the nutrient density of the diet (vitamins, minerals, trace elements). This is a beneficial side effect of altering the carbohydrate : fat ratio of the diet to induce gradual fat loss. An energy deficit of approximately 500 kcals (2000 kJ) per day is the maximum recommended, which should result in a gradual weight loss of 0.5 kg per week. Deficits of 1000 kcal (4000 kJ) per day result in more dramatic weight changes in some experimental trials, but these are typically reversed once the initial trial period or supervised programme has ended.

Although epidemiological studies suggest that physically active individuals are leaner than their sedentary counterparts,[44,67] randomized controlled trials of exercise as an isolated intervention do not support the idea that it can significantly modify body weight or total body fat by itself in those who are already obese,[37,67–70] even after 1 year of training. The most significant losses of weight and body fat with exercise generally occur in studies of men, in which relatively high intensities and durations of exercise are utilized, and the response also appears to be most robust in younger individuals who are not morbidly obese at the outset.[71] In a meta-analysis of randomized controlled trials of exercise and body composition changes during attempted weight loss, Garrow and Summerbell reported an average loss of 2.6 kg after 30 weeks of aerobic exercise in men, compared to 1.4 kg after 12 weeks in women.[67]

In contrast to total body fat mass, the effects of exercise on losses of the more metabolically important visceral fat stores[72] are stronger and more consistent across studies.[73–77] In a study of middle-aged obese women, Despres *et al.* found that aerobic exercise resulted in preferential losses of central adiposity,[77] just as has been seen in non-obese older adults.[31,34] Mourier *et al.* randomized obese middle-aged women with type II diabetes to aerobic exercise (3 days per week at 75% of maximal capacity for 45 min) over a 2-month period.[76] Compared to sedentary controls, exercising patients improved aerobic capacity by 41%, insulin sensitivity by 46%, while reducing subcutaneous adipose tissue by 18% and visceral adipose tissue by 48%, with no overall change in body weight. The change in visceral adipose tissue was highly correlated with the improvement in insulin sensitivity. Thus, other reasons to advocate such exercise in older adults include increases in aerobic fitness,[79] and insulin sensitivity,[80,81] and favourable changes in plasma lipoprotein profile and fibrinolytic activity,[82] which may occur with exercise independently of weight loss in the elderly. Notably, those with the highest levels of visceral fat to begin with appear to have the most pronounced losses of abdominal fat relative to total fat in response to exercise (referred to as the 'selectivity index'),[75] a finding with particular relevance to obese patients with an abnormal metabolic-risk profile.

Like aerobic training, progressive resistive exercise in the absence of dietary energy restriction appears to have only a small impact on total body weight or adipose tissue mass in young or old individuals. However, there is evidence of selective reduction in intra-abdominal fat stores with resistance training in studies of normal-weight young women,[83] and healthy older men and women,[35,84] which would be metabolically advantageous in those with pronounced visceral obesity.

Energy expenditure and intake, and consequently body weight, may both be influenced by aerobic and resistance training in unique ways. Much of the benefit of exercise in terms of energy balance comes from the changes in basal energy expenditure, rather than energy expended in the exercise sessions themselves.[15,36] Over the long-term, adaptations within muscle tissue in response to resistance training may significantly affect energy balance and contribute to the maintenance of a healthful body weight, while minimizing fat deposition.

The optimal approach to obesity must combine dietary and exercise changes in most cases, if long-term maintenance of body composition and weight shifts is to be sustained. An excellent example of such an approach is the Finnish Diabetes Prevention Study,[54] which combined dietary advice to lower fat and saturated fat intake, as well as increase fibre, and a combination of aerobic and circuit weight training exercise in obese, middle-aged subjects with impaired glucose tolerance. In this study, 522 men and women were randomized to experimental treatment or usual care groups and followed for 4 years, and the risk of incident diabetes was reduced by 58% in the experimental group, and was highly associated with achievement of the exercise and nutritional goals established.

**Muscle mass and quality**

There are numerous potential aetiologies for the consistently observed loss of muscle mass with ageing described in the literature.[50,55,85] Likely mediators of this sarcopenia include: (i) neuronal loss or dysfunction; (ii) loss of anabolic stimuli (oestrogen, dihydroepiandrosten-edione, testosterone, growth hormone, insulin-like growth factor I); (iii) catabolic illness (congestive heart failure, rheumatoid arthritis, chronic obstructive pulmonary disease etc.); (iv) medications (corticosteroids); (v) undernutrition (protein, energy, vitamin D); and (vi) disuse atrophy.

Therefore, the best approach to this problem is clearly multifactorial, and exercise and dietary recommendations for optimizing muscle mass in both health and disease are outlined in Tables 3 and 4. Both longitudinal and cross-sectional data document declines in muscle mass with advancing age,[86] especially in those who lose weight over time, but even in the presence of stable body weight.[87] Men appear to lose more muscle mass than women do, and this sarcopenia appears to be progressive over time,[86,87] in contrast to a levelling off of adipose tissue increases in the very old. There is some evidence to suggest that those who engage in higher levels of aerobic-type activities over their lifetime have greater lean mass or may lose less with age than their sedentary peers.[88–90] However, other studies suggest that such aerobic exercise, even practised at relatively high levels, is insufficient to prevent the typical age-related changes in muscle mass and strength.[86,91]

There are numerous studies in normal healthy older adults that indicate that high-intensity resistance training, in contrast to aerobic training, is associated with increases in lean body mass or muscle area, usually with minimal alteration of total body weight.[45,47,92,93] However, the observed adaptive response of skeletal muscle to resistance training in these studies is quite variable, likely influenced by the intensity and duration of the intervention, subject characteristics and the precision of the measurement technique itself.[92,94,95]

Unfortunately, most studies to date have included only healthy individuals,[15,45,96–100] and there is little clinical information other than age to allow insight into the wide range of muscle-tissue responsiveness to weightlifting regimens. It is clear from these studies and our own,[101,102] including frail elders, that advancing age impairs the hypertrophic response to resistance training, for reasons not yet completely identified. Taken together, the existing research suggests that both exercise-related variables as well as individual characteristics contribute to this wide range of lean tissue responsiveness to resistance training. Because hypertrophy requires synthesis of new proteins and structural changes, neural adaptation is the primary cause of immediate changes in strength in response to resistance training, and longer periods of training are associated with greater gains in muscle tissue. Exercise that does not involve high loading forces on the muscle is generally ineffective with regards to gains in both strength and muscle mass. Although it is possible to see changes in whole body lean tissue with progressive resistance training, even in the face of hypocaloric dieting in healthy middle-aged and older women,[36,103] or during protein restriction for preservation of renal function in kidney failure in frail chronically diseased elderly,[104] even energy intake sufficient for short-term weight maintenance (25 kcal/kg per day [90 kJ/kg per day]) appeared insufficient for muscle growth during training, and energy supplementation was necessary to induce significant hypertrophy.[105] Further research is required to separate out the effects of advanced age, nutritional deficiencies, hormonal status, disease attributes and extreme sedentariness, in clinical populations that may impair their ability to augment lean tissue with this mode of exercise, relative to healthy peers.

The basic dietary requirement for the maintenance of lean mass is the avoidance of weight loss with ageing, which always includes some lean mass as well as adipose tissue. Exact energy requirements will vary with individual characteristics including muscle mass, energy expenditure in physical activity and disease states, but approximately 30 kcal/kg per day (120 kJ/kg per day) is generally sufficient for weight maintenance. It has been shown that more lean (and adipose) tissue will be gained during resistance training if excess calories are supplied, even in healthy, normal weight older men.[106] Excess protein, in contrast to energy, is not necessary for additional muscle hypertrophy or strength gain during exercise,[15] despite much misinformation in the public domain and anecdote to the contrary. Even though protein requirements may be slightly increased in the elderly,[14] initiation of a progressive resistance training programme actually decreases protein needs by increasing nitrogen retention from the diet compared to the sedentary condition.[15] Therefore, protein sources and amounts commonly available in mixed healthy diets (0.8–1.2 g/kg per day) are sufficient for the retention and promotion of muscle mass in older adults of various activity levels.

Like protein supplementation, amino acid, vitamin, mineral and trace element supplementation has often been promoted for use in muscle hypertrophy. Vitamin D deficiency is associated with muscle atrophy and impaired contractility,[107,108] and should be supplemented in those with documented low 25-OH vitamin D levels or at high risk of osteomalacia (nursing home residents, hip fracture patients, home bound frail elders etc.).[109,110] The reduction in hip fractures demonstrated in nursing home patients treated with vitamin D and calcium is thought by some to be due to an effect of vitamin D on neuromuscular function and fall rates, given the rapid onset of protection offered by this treatment compared to the time course of changes in bone density that may have occurred. Supplementation of the amino acid derivative creatine has been advocated for the improvement of exercise performance as well as muscle mass. Although enhancement of high intensity aerobic exercise performance may be seen in some studies, short-term increases in 'lean mass' after only 5–7 days of creatine ingestion appear to be due to acute cellular swelling due to osmotic effects of creatine and not hypertrophy of contractile proteins.[111] There is no evidence for supplementation or excess consumption of other micronutrients for the purpose of optimizing muscle mass with ageing or in response to training.

**Bone mass**

Bone mass begins to decrease even before the menopause in women, and accelerates in the perimenopausal years, with continued declines into late old age.[112] Similar patterns are seen in men, without the acceleration associated with loss of ovarian function seen in women.[113] As with losses of muscle tissue, many genetic, lifestyle, nutritional and disease and medication-related factors enter into the prediction of bone density at a given age.[114–122] The primary physical activity and diet recommendations relating to bone density and osteoporotic fracture prevention are indicated in Tables 3 and 4.

The primary dietary advice relating to achievement of peak bone mass in early adulthood and maintenance thereafter is to ensure adequate intake of calcium beginning in childhood and continuing throughout life. Calcium intakes of 1200 mg/day are recommended as adequate intake currently for men and women over the age of 50,[123] based on a variety of epidemiological and experimental trials.[30,118,124–134] Although the experimental data on fracture prevention with calcium alone is inconsistent across trials, it appears most effective in those with low habitual dietary intakes, and in combination with vitamin D supplements. Most older adults consume less than 500 mg/day, leaving much room for improvement. The calcium may be taken as food (primarily dairy products or fortified juices) or supplements for those who are lactose intolerant or who have an aversion to dairy products. Low- or non-fat dairy products offer a calcium alternative to those who are also reducing energy or saturated fat intake for other reasons. In addition to calcium, vitamin D assumes an increasing importance in the later postmenopausal years, when decreased cutaneous production of vitamin D and renal hydroxylation to its active metabolite limit the endogenous supply of this nutrient.[110,135–140] Adequate intake of vitamin D is currently set at 400 IU per day for men and women aged 51 through 70 years, and 600 IU per day for those over the age of 70 years, based on studies of both bone mineral density and fracture risk related to vitamin D intake and status.[123] Vitamin D may be consumed in fortified dairy products if sufficient quantity can be ingested each day, but may be more conveniently supplied as 1–2400 IU tablets or as part of a multivitamin pill daily.

In addition to adequate calcium and vitamin D, there is some evidence that excess alcohol consumption may adversely effect bone mineral density or increase risk of osteoporotic fracture;[122,141] therefore moderation of alcohol intake is recommended. The adverse consequences of excess alcohol intake on testicular atrophy, myopathy, peripheral and central neurological function, gait, balance, coordination, and judgement, in addition to impairment of bone metabolism, may combine to produce a high-risk profile for injurious falls and fractures in the elderly. Finally, as is the case with muscle mass, weight loss and inadequate intake of protein and energy will lead to losses of bone and increase hip fracture risk.[142] Thus, prevention and treatment of energy or protein malnutrition and early assessment of unintentional weight loss is part of the management plan for optimal bone mass and health.

Habitual exercise has a relatively potent effect on bone mineral density in epidemiological and cross-sectional investigations,[118,143,144] and both weight-bearing aerobic exercise,[24,26,28,145–149] as well as resistive exercises,[23,47,150–153] have positive effects in experimental trials. The weight of the evidence suggests that while aerobic exercise may be effective as a prevention strategy in younger adults, it is likely that significant shifts in bone mineral compartment in older adults are more robust with weightlifting exercise. In addition, it has been shown that high-impact forces to bone (jumping, using weighted vest with stepping, jumping, and resistive activities) are likely to have greater effects than low-impact or low-loading activities.[22] By contrast, wearing a weighted vest without the additional prescription of specific exercises has no impact on bone density or functional status.[154] The difficulty comes in the attempt to prescribe high-impact activities (such as jumping while wearing a weighted vest) in older adults with both osteoarthritis of the hips and knees, as well as risk of osteoporotic fracture and falling. It is doubtful that high-impact activities, such as jumping, would be feasible in such a patient profile, and could result in exacerbation of arthritis as well as fall-related injuries. Therefore, in such cases a low impact but high loading form of exercise (such as seated and standing weightlifting with machines or free weights) would be both effective and tolerable. In general, because the effects of muscle contraction on bone appear to be primarily regional (electromagnetic field stimulation of osteoblast function), rather than systemic, it is advised that muscle groups connected to bones of relevance to osteoporotic fracture be emphasized in such a programme (e.g. spinal extensor muscles, hip abductors, hip extensors, knee extensors, knee flexors) as well as those associated with gait and balance (ankle plantar flexors and dorsiflexors).

**Recommendations**

Despite the wealth of accumulated data on the health benefits of regular exercise and good nutrition, including optimization of body composition, the lack of formal training in these disciplines for most physicians has hindered the adoption of evidence-based practice in these domains. In particular, there are few appropriate, concise strategies for specific indications, such as augmentation of muscle mass or bone density, or reduction of visceral fat, and limited formal clinical guidelines for the assessment, prescription, promotion and facilitation of adherence to such advice, although they are beginning to appear in the geriatric scientific literature.[155]

The process in relation to body composition, or any other goal, involves assessment, prioritization of treatment in relation to health risks, administration of a specific dietary and exercise prescription, monitoring of progress, and provision of feedback and rewards for behavioural change. These elements are summarized in Table 5. It should be noted that shaping behaviour with the introduction of only one change at a time is recommended for improved adoption of a new lifestyle parameter, so that the patient is not overwhelmed and frustrated by the demands of multiple prescriptive elements. Economization of prescription should always be practised, in lifestyle recommendations as is done in pharmacological management of disease. So, for example, if concurrent goals of decreased visceral fat and increased bone density are contemplated in an older woman with both osteoporosis, recurrent falls, and type II diabetes, it can be

**Table 5.** Implementation of exercise and dietary recommendations for body composition

| | Adipose tissue | Muscle | Bone |
|---|---|---|---|
| Assessment | Waist circumference >90 cm†; body mass index >26 kg/m$^2$; fasting insulin, glucose, lipoprotein profile, uric acid; high fat/saturated fat intake. | History of falls; muscle atrophy on examination; slow chair rise time and/or gait speed; weight loss; low calorie intake. | History or physical exam evidence of osteoporotic fractures; loss of height; weight loss; dual energy X-ray absorptiometry scan more than 1 SD below normal for age and sex; low 25-OH vitamin D level; low calcium intake. |
| Prescription | Aerobic or resistance training; energy restriction; fat restriction. | Resistance training; energy balance | Resistance and high impact training; calcium; vitamin D |
| Monitoring of progress | Change of exercise and dietary behaviours; change in waist circumference; change in body weight; reduction in metabolic abnormalities; reduced need for medications for diabetes, hypertension, dyslipidemia, gout. | Change of exercise and dietary behaviours; increase in muscle strength; improvement in stair climb time, chair rise time, gait speed, functional independence. | Change of exercise and dietary behaviours; stabilization or increase in bone density; maintenance of bone mass; increase in 25-OH vitamin D level to normal range; reduction in PTH or alkaline phosphatase if initially elevated. |

†Measured at the midpoint between the lower costal margin and the superior iliac crest in centimeters.

seen that the prescription of progressive resistance training offers benefit for all these indications, whereas aerobic training would be less effective in isolation as an intervention. Prescriptions which are 'negative', such as joule and fat restriction, may be less appealing than 'positive' prescription, such as weightlifting or aerobic exercise, particularly in the lifelong obese, patient with multiple failed previous attempts at weight loss through dieting. The substantial metabolic benefits of exercise in visceral fat reduction and improved metabolic profile, even in the absence of dietary change or weight loss,[19,74,75,77] should lead the clinician to confidently prescribe such activity as an initial step, or even the only change in patients who are difficult to treat. In all cases, it is important to remember that the behavioural change itself (adoption of exercise, restriction of fat intake) is the factor that is to be monitored and followed, as body composition changes and related diseases are long-term outcomes that sometimes require sophisticated measurement techniques to document, or extended periods of follow up that may be discouraging to the individual patient. However, a change in behaviour (exercising three times per week, always using the stairs etc.) is visible and easy to document on a weekly basis by the patient or the health-care practitioner for review and provision of appropriate feedback and rewards.

## Conclusions

In summary, exercise and dietary interventions are useful to combat age-associated increases in fat mass and decreases in lean mass (muscle and bone), which are typically seen to varying degrees in older adults. Exercise is adjunctive to energy restriction in the treatment of generalized and central obesity, and will consequently contribute to the management of this risk factor for many chronic diseases. The most clinically important component of body fat, visceral adiposity, is preferentially lost during energy restriction, as well as in response to aerobic or resistive exercise, especially in those with initially large abdominal stores. Resistance training, in the presence of adequate energy and protein intake, will also augment muscle mass and bone density, and is consequently of central importance as an exercise prescription for the prevention of functional impairment and osteoporotic pain and fractures in older men and women. Bone mass is further optimized by prevention of weight loss, adequate calcium and vitamin D intake or enhancement of endogenous cutaneous production of vitamin D, and repetitive high-impact forces to the skeleton. As exercise increases overall energy expenditure and consequently nutritional requirements, in a variety of ways, it may also counteract the risk for vitamin and mineral deficiencies, which is seen in frail older adults consuming a very small volume of food due to their reduced energy requirements, assuming that food intake increases in response to altered needs imposed by a higher physical activity level. In combination then, it is possible to offer evidence-based guidelines for diet and exercise patterns across the lifespan, which will minimize adverse consequences of genetic predisposition, biological ageing, disease and medication use on body composition. This should have a substantial impact on the burden of chronic diseases related to body composition, including the most important causes of morbidity and mortality in modern societies: cardiovascular disease, diabetes, stroke, obesity, arthritis, osteoporosis, frailty and functional dependency.

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