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Weight Management in Older Adults

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Abstract

As the number of older adults increases rapidly, the national epidemic of obesity is also affecting our aging population. This is particularly concerning given the numerous health risks and increased costs associated with this condition. Weight management is extremely important for older adults given the risks associated with abdominal adiposity, which is a typical fat redistribution during aging, and the prevalence of comorbid conditions in this age group. However, approaches to weight loss must be considered critically given the dangers of sarcopenia (a condition that occurs when muscle mass and quality is lost), the increase risk of hip fracture with weight loss, and the association between reduced mortality and increased BMI in older adults. This overview highlights the challenges and implications of measuring adiposity in older adults, the dangers and benefits of weight loss in this population, and provides an overview of the new Medicare Obesity Benefit. In addition we provide a summary of outcomes from successful weight loss interventions for older adults and discuss implications for advancing clinical practice.

Keywords

obesity; geriatrics; body mass index; body fat; weight loss

Introduction

Life expectancy in the United States has dramatically increased over the past century. In the year 1900, the mean life expectancy was 47 years, compared to 78.8 years today [1]. This

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Conflict of Interest

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phenomenon is contributing to population growth leading to an increased number of adults aged 65 and older, which is expected to almost double from 43.1 million in 2012 to 83.7 million in 2050 [2].

The size and composition of this population will largely depend on drivers of mortality, including obesity [2]. Obesity is a pandemic and is increasingly prevalent across the globe. Often overlooked, between 2004 and 2012, the prevalence of obesity in adults aged 60 and older in the United States increased by 4.4% from 31.0% to 35.4% [3]. Such a growing prevalence in older adults is particularly concerning due to the well-established association between obesity, disability [4] and the increase in absolute mortality risk up to age 75 [5]. Obesity is associated with multiple conditions including hypertension, hyperlipidemia, diabetes, and sleep apnea [6] as well as osteoarthritis [7], cancer [8], and cognitive dysfunction [9]. The relationship between obesity and many of these conditions helps explain why people with obesity often experience premature death [10]. In addition to increasing disability, morbidity, and mortality, obesity, is associated with greater health care costs. Obesity accounts for up to 2.8% of healthcare expenditure [11] and this number is likely to grow as the prevalence of obesity increases. In a 2008 study, older men and women who were overweight or obese at age 65 spent 6–13% and 11–17% more on healthcare throughout their lifetimes respectively [12].

Obesity differs in younger versus older adults. Aging is associated with loss of fat-free mass (primarily skeletal muscle) and increases in fat mass up to age 70 [13]. In the aging process, fat is redistributed centrally from the limbs to the trunk of the body. Physical manifestations of aging lead to a progressive increase in body fat, but also promote sarcopenia, the loss of skeletal muscle mass combined with low muscle function [14]. Some of the risks associated with obesity differ by age group. For example, higher BMI is associated with lower odds of having hypertension in older adults compared to younger adults [15] and greater body weight increases the risk of death from any cause and cardiovascular disease between age 30 and 74 years [5]. These differences among others require consideration when approaching weight management in older versus young adults.

Identifying Obesity in Clinical Practice and the Limits of BMI as a Measure in Older Adults

Body mass index (BMI) is the traditional metric used to assess adiposity by dividing weight (in kg) by height (in m^2). This assessment is inexpensive and quick to perform, making it a practical measure to use in clinical settings. However, there are numerous ways in which BMI is a suboptimal measure for obesity in older adults. First, age-typical loss of height due to vertebral body compression and angulation of the spine cause BMI values to overestimate fatness [16]. Second, BMI does not account for fat distribution and it has been shown that visceral fat is characteristic of metabolic syndrome [17], type 2 diabetes, impaired glucose tolerance [18], aortic stiffness [19], and myocardial infarction in women [20]. Hence, BMI has been largely criticized for use in older adult populations because it does not account for age related changes in adipose tissue – specifically the ratio between fat mass and fat-free mass [14, 21]. As people age, fat-free mass is replaced by fat mass, therefore BMI

underestimates fatness [21]. This change can often lead to normal weight obesity [22], which is defined as a normal BMI (18.5–25kg/m^2) but a high body fat percentage. Normal weight obesity increases risk for cardiometabolic dysregulation, metabolic syndrome, endothelial dysfunction, cardiovascular risk factors, mortality [22], and disability in older adults [23]. Since overall obesity is only slightly predictive of metabolic syndrome [17], type 2 diabetes, and impaired glucose tolerance [18], and not predictive of aortic stiffness [19], and myocardial infarction [20], measures of adipose distribution as opposed to overall fatness should be used when assessing risk.

Clinically valid alternative approaches exist for assessing fatness that range in ease of use and cost to perform. In a study comparing weight, BMI, waist circumference, hip circumference, and waist-hip ratio, waist circumference was the best predictor of mobility disability in men and women [24]. Waist-hip ratio also accurately predicts disability outcomes in men [24]. These anthropometric measures are as inexpensive and easy to perform in practice therefore, they may be used practically to provide additional risk stratification among overweight and obese individuals [25•]. Densitometry can also be used to estimate body composition by measuring total body density. This method involves recording the individual's weight in air and underwater, and uses density properties to estimate adiposity. Though it is accurate, it is time-consuming, complicated, and places physical demands on the individual, making it unsuitable for many older adults and those with morbid obesity [26]. Dual-energy X-ray absorptiometry, magnetic resonance imaging, and computer tomography are often used to measure adiposity in small research studies, however they are expensive, time-consuming, and pose some health risks [26], and are therefore largely impractical for clinical settings.

Benefits of Weight Loss in Older Adults

Given the plethora of health risks associated with aging, some might ask, why treat obesity in older adults? Obesity is associated with many medical complications, such as metabolic abnormalities, arthritis, pulmonary abnormalities, urinary incontinence, cataracts, and cancer, as well as decreased physical function, quality of life and increased frailty [13]. Compared to other chronic conditions, there is a limited literature base supporting the benefits of weight loss in older adults. However, as summarized in Table 1, existing studies show encouraging results.

Multiple weight loss interventions have been designed to address cardiovascular disease in obese older adults. Cardiovascular disease is the leading causes of death for persons over 65 years of age [27]. A 12-week weight loss intervention showed improved insulin resistance and cardiometabolic risk factors in obese older adults (mean age of 65.5 years) [28]. Exercise and exercise plus caloric restriction were shown to improve insulin sensitivity by 31% and 30% and reduce fasting glucose by 27% and 37% respectively. Blood pressure and lipid profile improved in both groups without a significant difference between comparison and control groups. An 18-month weight loss and physical activity intervention significantly improved mobility based on a 400-meter walk test in overweight and obese older adults with cardiovascular disease or cardiometabolic dysfunction [29]. Of particular importance, a study by Rejeski and colleagues found that weight loss must be coupled with physical

activity in order to have a significant effect, as opposed to physical activity alone. An 18-month trial of 288 overweight and obese older adults with, or at risk for, cardiovascular disease showed weight loss and physical activity reduced leptin and high sensitivity interleukin-6, which are two common inflammatory biomarkers [30]. Chronic inflammation is associated with adiposity and increases risk for cardiovascular disease, diabetes, and physical disability [30]. Theoretically this intervention should reduce disease and disability in older adults, however long-term follow up is necessary to determine whether this is true.

A randomized controlled trial of an approximately 7-month weight loss and diet intervention in 585 obese older adults (subset of mean age of 66.5 years) with hypertension resulted in a mean 3.5kg reduction in body weight and a decreased the need for antihypertensive medications by 30% [31]. However, this study did not evaluate loss of lean mass and bone density as a potential risk of dietary weight loss interventions in older adults that do not include an exercise component. In a trial of 316 overweight and obese older adults (mean age of 69.0 years) with knee osteoarthritis, Messier et al. demonstrated an 18-month intervention including exercise and dietary weight loss significantly improved physical function as it related to activities of daily living [32]. Pain was reduced by 30.3% within the 18-month intervention period and mobility also improved. Notably, the diet only group did not significantly improve pain or mobility, which highlights the importance of exercise in weight loss interventions.

A recent study found that diet and exercise-induced weight loss effectively reduces pain and improves function and quality of life in older adults (mean age of 66.0 years) with knee osteoarthritis in comparison to diet or exercise alone [33]. The authors achieved greater improvements in function and mobility than in their previous study [32], which they attribute to the use of a social cognitive behavioral framework. Additionally, lean mass increased by 3% relative to total body weight at 18-months which substantially contributes to the encouraging results from weight loss interventions for older adults. Villareal and colleagues reported that a 1-year weight loss and exercise intervention for obese older adults (mean age of about 70 years) was associated with a loss of 9% of body weight, improved measures of frailty, including the Physical Performance Test, VO_{2peak}, and the Functional Status Questionnaire [34]. This study underscores that exercise should be combined with dietary changes in order to achieve weight loss and treat frailty in older adults. Neither diet nor exercise was as effective solely and this study proved the importance of combining these two modalities together.

Two studies by Beavers and colleagues [35, 36] looked at the effects of a weight loss and physical activity in older adults. In the first study of 271 older adults (mean age of 65.4 years), overall weight loss predicted improvement in mobility disability and walking speed [35]. Loss of fat mass was associated with larger improvements in walking speed than loss for body mass. Results also showed loss of lean mass during intentional weight loss did not negatively impact physical function. Based on this finding, the authors suggest that implies muscle quality, rather than quantity, is important for functional performance in older adults. Two hundred and eighty-eight overweight and obese older adults (mean age of 67.0 years) participated in the second study [36]. During the 12- to 18-month intervention, the physical activity and weight loss group significantly reduced lean and fat mass compared to the

physical activity and the weight loss groups, which resulted in a greater percentage of lean mass overall. Improvement in diastolic blood pressure, glucose and HDL-C were associated with loss of fat mass where as improvement in triglycerides, insulin and HOMA-IR were associated with change in fat mass and lean mass. The authors suggest reduction of fat mass and preservation of lean mass should provide maximal cardiometabolic benefits, however, the relationship between the two is complex and should be further explored. Consistent with the other studies discussed in this section, maximal benefit was experienced by individuals in the weight loss and physical activity group as opposed to physical activity alone. These outcomes are important to consider when recommending interventions for older adults given the associated between frailty and sarcopenia [37].

Dangers of Weight Loss

The dangers of weight loss in older adults are a legitimate concern of providers and researchers. As demonstrated in both observational and clinical trials, weight loss leads to loss of fat mass and fat-free mass. Approximately one-quarter of all weight lost in older adults during intentional weight loss interventions is fat-free mass [38] which contributes to sarcopenia, the loss of muscle mass and quality. Sarcopenia is associated with impaired instrumental activities of daily living [39], disability [40], and frailty [41]. Those with obesity are at high risk of developing sarcopenic obesity, which affects 42.9% and 18.1% of men and women aged 60 and older respectively [42]. Though sarcopenia and sarcopenic obesity are more prevalent in men, women with these conditions have a higher mortality risk [42]. However, studies of sarcopenia and sarcopenic obesity are limited by definitional and case identification discrepancies as well as difficulty measuring muscle quality [42]. Sarcopenia is also associated with increased healthcare costs. It was estimated that in 2000, the direct cost of sarcopenia in the United States was $18.5 billion or 1.5% of total direct healthcare costs [43]. The same study found if the prevalence of moderate to severe sarcopenia was reduced by 10% than $1.1 billion would be saved annually. Unfortunately, very little has been done to emphasize the importance of resistance training and nutritional management to mitigate weight loss induced sarcopenia. A public health campaign targeting sarcopenia has the potential to improve health outcomes and reduce health care costs in older adults.

Unfortunately, some clinical providers have also resisted recommending weight loss in older adults due to the finding of an “obesity paradox” which describes the relative reduction of risk of mortality for older adults with increase BMI [5, 44]. This phenomenon has been observed for overall mortality [44] and disease-specific mortality, including heart failure [45], hypertension and coronary artery disease [46], stroke [47], and others [48]. Not only is weight a potential protective factor, but longitudinal studies show weight loss is predictive of mortality in older adults [49–51]. Additionally, weight loss (regardless of intentionality) in older women is associated with 1.8 times the risk of subsequent hip fracture [52], and older white men who experience extreme weight loss (10% body weight) after age 50 are also at increased risk of that injury [53].

Though multiple studies support the obesity paradox, it is important to note that this observation does not suggest that obesity is a benign condition in older adults. First, much of

the obesity paradox might be due to the associated declining health of unintentional weight loss in older adults. In this respect, low BMI associated with end-stage chronic illness and failure to thrive is associated with high rates of mortality. Though longitudinal studies show weight loss is associated with mortality, results do not delineate between unintentional versus intentional loss and therefore may be confounded by weight loss accompanying serious disease [13]. Second, It has been suggested that increased BMI is not actually protective but instead, a small remaining life span hides impact of obesity and persons susceptible to complications of obesity died younger. Though being overweight might be modestly protective, there are numerous complications of obesity that are associated with reduced function and increased mortality [13]. Finally, multiple instances show limits to the protective factors of the paradox [10]. For example, a study of middle aged people with heart failure showed those with morbid obesity (BMI ≥40 kg/m^2) were associated with higher risk of mortality compared to the obese individuals [54].

Medicare Obesity Benefit

In 2011, the Centers for Medicare and Medicaid Services introduced a Medicare obesity counseling benefit for individuals with a BMI of $30kg/m^2$ or higher [55]. This benefit supports Intensive Behavioral Therapy that is delivered in a 15-minute individual session or a 30-minute group session. Therapy is offered for 6 months and if patients have lost 3kg in that period, they are eligible for an additional 6 months of behavioral counseling. Those who are ineligible to continue at the 6-month point are required to wait another 6 months before being reassessed by their primary care provider as to whether they have readiness to change.

Though this benefit is a significant step towards addressing the growing obesity epidemic in older adults, there are three notable criticisms [25•]. Firstly, the benefit was largely developed based on data from studies of adults less than 65 years old [25•], and as previously explained, older adults typically lose fat-free mass as they age as opposed to fat mass, which puts them at risk for sarcopenia and sarcopenic obesity [14]. Since unintentional as well as intentional weight loss can be associated with health risks in older adulthood [52] it is important to consider multiple factors when recommending weight loss to individuals. As previously discussed, weight loss has many positive impacts when coupled with physical activity [30, 32, 33, 29, 34, 31, 28]. Therefore, focusing on wellness versus solely weight loss will produce better outcomes. Secondly, in order for Medicare beneficiaries to receive the benefit, they must meet the BMI threshold of $30kg/m^2$. BMI is not an accurate tool for measuring adiposity in older adults [14, 43]. Individuals with high body fat and low muscle may have a healthy BMI, but actually be at risk for adverse cardiometabolic outcomes, mortality [56] and disability [23]. As the benefit is currently described, it will exclude Medicare beneficiaries who may greatly benefit from it. Lastly, the benefit poses practice management challenges [25•]. It may not be possible to effectively deliver Intensive Behavioral Therapy in 15-minute session over 6 months in a busy primary care setting. The benefit also poses barriers to reimbursement of clinicians who are integral in obesity treatment, such as dietitians.

Nutritional Interventions

Dietary change is a key component of weight loss interventions for older adults [30, 36, 35, 32, 29, 34, 31, 28]. However, adopting a new diet often requires significant lifestyle modifications, so individuals should be appropriately supported. Health confidence is a simple way to assess patient engagement [57], which is associated with desirable patient outcomes [58]. It can be measured using a 0–10 point scale ranging from not very confident to very confident and a score of seven or above indicates an individual is confident enough to engage [57]. Measuring confidence related to making a health behavior change is an important first step when prescribing a nutritional intervention because it allows the patient and clinician to know if additional education, support, or active health coaching is needed if confidence is low. Health confidence should be continually assessed through the process as a way to support and reinforce the patient's progress, identify goals, and prioritize options [57]. The individual and clinician should work together to develop these weight loss goals in order to keep them realistic and achievable. Motivational interviewing can also be used to bolster the individual's confidence. This focused and goal-driven form of counseling helps the individuals identify intrinsic motivations necessary to drive behavior change [59] and has been specifically shown to increase adherence to weight-control programs [60]. Mode of delivery of treatment should also be considered. Dietitians may be more effective than physicians at working with patients to maintain dietary change to reduce blood cholesterol [61]. Though there is limited research looking at weight loss, if available, dietitians may be the best specialists to work with individuals due to their in depth education in nutrition and dietary change [61].

In order to achieve weight loss, energy intake should be reduced by 500–1,000kcal/day and dietary fat should be reduced to 30% of total energy intake maximally [62]. A large trial called Look AHEAD (Action for Health in Diabetes) developed a dietary intervention in which older overweight and obese individuals with type 2 diabetes consumed 1,200–1,800kcal/day depending on initial weight [63]. Meal replacements were consumed during breakfast and lunch because they are associated with greater weight loss compared to conventional diets, make it easier to adhere to portion control, and reduce food choice [64]. Dinner consisted of conventional food and participants were encouraged to eat fruits and vegetables within their calorie limit. The dietary intervention was combined with ≥175 minutes of exercise per week in an effort to achieve ≥7% reduction of body weight. Results after one year showed an average loss of 8.6% of body weight [63]. However, once weight loss is achieved, it is important to develop a plan for weight maintenance.

The Society for Sarcopenia, Cachexia and Wasting developed nutritional recommendations for persons with sarcopenia [65]. The recommendations focus on halting or reversing muscle loss associated with the disease. Older persons should ingest 1.0–1.6g of protein/kg/day and spread consumption equally throughout the day. A leucine-enriched balanced amino acid supplement should be taken to slow muscle loss, which is especially important for older adults who exercise. In addition, vitamin D should be supplemented in persons with values below 100nmol/L. A minimum of 60–90 minutes a week of resistance and aerobic activity is also recommended in order to slow muscle loss.

Physical Activity/Exercise Interventions

Strong evidence supports the effectiveness of physical activity interventions for older adults. Exercise is important for older adults to reduce their risk of impairment because muscle strength and power are associated with function and mobility in this population [66]. General energy expenditure has been linked to lower mortality risk in geriatric patients [67]. The Lifestyle Intervention and Independence for Elders (LIFE) pilot study tested a physical activity intervention in 424 sedentary adults aged 70 years or older [68]. Though participants were not included or excluded based on weight, the average BMI of the intervention group was 30.7kg/m^2, which meets threshold for obesity. The Short Physical Performance Battery (SPPB) was used to assess risk of institutionalization, morbidity, mortality, and disability. SPPB scores significantly improved in the intervention group and roughly two-thirds of participants improved by greater than one point (0.5 point increase indicates meaningful change). A more recent study of the intervention reported a reduction in major mobility disability over 2.6 years [69]. A follow up analysis of the pilot data showed participants with sarcopenia equally benefited from the intervention [70]. Though change in sarcopenia status was not statistically significant (p=0.20), results showed older adults with sarcopenia improved physical performance in response to physical activity.

The American College of Sports Medicine and the American Health Association recommends that older adults should be physically active in order to prevent and treat disease [71]. Activity should include aerobic, muscle-strengthening, flexibility, and balance exercise. Minimally this should include: moderate-intensity aerobic activity for 30 minutes five days per week or vigorous-intensity aerobic activity for 20 minutes three days a week, 10–15 repetitions of 8–10 major muscle group strengthening exercises two or more nonconsecutive days each week, 10 minutes of flexibility activities at least two days a week, and balance exercises three times a week for fall prevention. These recommendations are for older adults who are generally healthy so modifications are necessary for older adults with chronic disease, low fitness and/or functional limitations. Examples of modifications are increased weight bearing activities for persons with osteoarthritis or reduced activity for individuals with impairment in activities or daily living. For older adults with low fitness, activity should be introduced in a gradual or stepwise approach and more activity above the minimum requirement may be necessary with older adults aiming to lose weight.

Pharmacological and Surgical Weight Loss Interventions

There are several other weight loss approaches that are increasingly used in practice. Currently, commonly used weight loss medications approved by the Food and Drug Administration are diethylpropion, phendimetrazine, benzphetamine and phentermine for short-term use (less than 12 weeks) and orlistat, lorcaserin, and phentermine plus topiramate for long-term use [72]. Yanovski and Yanovski [72] found long-term drug use showed modest improvements in weight, disease progression, and health risk factors, however, anywhere from 30–60% of individuals did not experience clinically significant weight loss (≥5% body weight). Though pharmacological approaches are effective in combination with behavioral treatment, most safety and efficacy studies of medications have focused on adults under 65 years old, therefore insufficient data exists in order to recommend use for older

adults. Pharmacotherapy is not often prescribed in this population due to the lack of data in addition to polypharmacy [73]. Endoscopic devices, such as the EndoBarrier Gastrointestinal Liner, have been tested in Europe and shown to be effective [74], however, they have not been approved in the United States. Additionally participants were between 18–55 years of age and morbidly obese, therefore the results are not generalizable to the older adults population. Bariatric surgery is considered the most effective weight loss intervention and is currently recommended by the American College of Cardiology/ American Health Association for adults with a BMI ≥40kg/m^2 or ≥35kg/m^2 with obesity-related comorbid conditions [75]. There are no upper age limits for Bariatric surgery, yet increasing numbers of older adults who physiologically and functionally could be subjected are being observed. A review on this topic and evaluation is outside the scope of this paper but have been discussed elsewhere [76]. In practice, adults over 60 years of age have received bariatric surgery though there have not been any randomized controlled trials. What little data exists shows older adults have low mortality after surgery and an acceptable risk-to-benefit ratio [77]. It has been suggested that chronological age should not be the determining factor as to whether surgery should be performed but rather a geriatric assessment should be conducted and a risk/benefit analysis should be discussed with the patient [76].

Interdisciplinary Approaches

Interdisciplinary approaches have long been used in the field of geriatrics. Though there are a variety of terms used to describe this type of approach, the keys elements are coordination and communication between an interdisciplinary team and the patient and family. This type of approach has been shown to improve outcomes, such as reduce home health care use [78], length of hospital stay, and hospitalizations [79]. Primary care interdisciplinary teams have been associated with improved quality of life, functional autonomy, and reduced use of acute care health services in older adults with chronic conditions [80]. Weight management in older adults should be approached in the same way. Since lifestyle interventions are most widely recommended for weight loss in older individuals, team-based care may include primary care physicians, nurses, dietitians, exercise specialists, and behavioral therapists. Due to the many comorbidities associated with obesity, individuals may also receive care from specialists. Effective communication should occur between all providers in order to coordinate care and optimize outcomes.

Patient-centered care is another important aspect of an interdisciplinary approach. Weight loss interventions require a significant amount of effort and change to an individual's lifestyle. For an older adult, these changes must be considered in addition to common challenges that are experienced in the aging process. A large body of research demonstrates that quality of life for older adults, based on life satisfaction and clinical outcomes, is maintained or even increased with physical activity [81]. Interestingly, quality of life does not necessarily depend on change in fitness. Though these findings and this review highlight the beneficial effects of weight loss and exercise, it is important to consider patient preferences and include them in goal setting [81]. This approach increases the likelihood of helping older adults to appreciate the logic of the recommended activity and allows the practitioner to motivate and develop goals with the individual. Additionally, the

recommended activity should be tailored to the person's specific goals. For example, if the patient's goal is to improve mobility, a walking program may be appropriate. The overarching purpose is to increase quality of life so the individual is central to informing this process.

Conclusions

The number of older adults is projected to increase substantially in the coming decades and addressing obesity is essential for the health of this rapidly growing population. Though the "obesity paradox" has contributed to a lack of attention to addressing obesity as a major health problem in older adults, weight loss and improved fitness in obese older adults has been shown to improve function and multiple health indicators. Though physical activity and diet alone can improve outcomes, randomized controlled trials showed better outcomes when they were combined. The process of activity prescription should be patient-centered in order to develop a plan that is relevant to the older adult's goals and achieve the overarching purpose of improved quality of life.

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Table 1

Positive Results from Selected Studies of Weight Loss Interventions for Overweight and Obese Older Adults

Intervention Name or Locale		Population	Age Range	n	Study Design	Intervention Duration	Description of Intervention	Positive Outcomes
Cooperative Lifestyle Intervention Program (CLIP)	Beavers 2013 [30], Beavers 2014 [36], Rejeski 2011 [29]	Ambulatory, overweight or obese, community-dwelling adults with either cardiovascular disease or cardiometabolic dysfunction	60–79 years	288	Randomized Controlled Trial	12–18 months	-Group, individual and independent exercise sessions - 150 minutes per week of aerobic activity -Caloric reduction	-Reduced weight, leptin and high sensitivity interleukin-6 -Increased lean mass relative to body weight -Improved mobility, diastolic blood pressure, glucose, high density lipoprotein cholesterol, insulin, triglycerides, and Homeostatic model assessment Insulin Resistance
Cooperative Lifestyle Intervention Program (CLIP), Diet, Exercise, and Metabolism for Older Women (DEMO), Optimizing Body Composition for Function in Older Adults (OPTIMA)	Beavers 2013 [35]	Overweight and obese adults	50–79 years	271	3 Randomized Controlled Trials	4–18 months	-Various exercise activities -Caloric restriction - Pioglitazone treatment (OPTIMA)	-Reduced weight, fat mass associated with increased walking speed and mobility disability -Improved mobility and walking speed
Arthritis, Diet, and Activity Promotion Trial (ADAPT)	Messier 2004 [32]	Overweight or obese community-dwelling adults with knee osteoarthritis	≥ 60 years	316	Randomized Controlled Trial	18 months	-Home and facility-based exercise sessions -Caloric restriction -Individual and group dietary weight loss sessions	-Reduced weight and pain -Improved physical function and mobility
Intensive Diet and Exercise for Arthritis (IDEA)	Messier 2013 [33]	Overweight and obese community-dwelling adults with knee osteoarthritis	≥ 55 years	454	Randomized Controlled Trial	18 months	-3 hours of aerobic exercise per week -Caloric restriction and nutritional education	-Reduced weight, fat mass and pain -Improved function and mobility -Increased lean mass relative to body weight
Washington University School of Medicine	Villareal 2011 [34]	Obese, sedentary adults with mild-to-moderate frailty	≥ 65 years	107	Randomized Controlled Trial	12 months	-3/90 minute group exercise sessions per week -Caloric deficit	-Reduced frailty -Improved physical performance,

Intervention Name or Locale		Population	Age Range	n	Study Design	Intervention Duration	Description of Intervention	Positive Outcomes
							-Weekly group sessions with a dietitian	VO_{2peak}, and functional status -Decreased weight, fat mass, and lean mass
Trial of Nonpharmacologic Interventions in the Elderly (TONE)	Whelton 1998 [31]	Adults with hypertension	60–80 years	975 (585 obese)	Randomized Controlled Trial	≥ 7 months	-Group and individual sessions with nutritionists and exercise counselors -Reduced sodium diet	-Reduced weight and need for antihypertensive drug therapy
Case Western School of Medicine	Yassine 2009 [28]	Obese, sedentary older adults with metabolic syndrome	Reported mean and standard deviation: 65.5 ± 5.0 years	24	RCT	12 weeks	-5/50–60 minute exercise sessions per week -Caloric restriction -Weekly sessions with a nutritionist	-Reduced weight, fasting glucose and blood pressure -Improved lipid profile and insulin sensitivity