A systematic review of the separate and combined effects of energy restriction and exercise on fat-free mass in middle-aged and older adults: implications for sarcopenic obesity

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The systematic review presented here assessed the effects of energy restriction (ER) and exercise (EX) on fat-free mass (FFM) in overweight and obese middle-aged and older adults. PubMed was searched using the key words “weight loss or energy restriction” AND “skeletal muscle or body composition,” with limitations set for “human” and “middle-aged and aged.” Results from 52 studies are reported as the percentages of EX (mainly aerobic training), ER, or ER+EX groups that had a specified change in body weight and FFM, since insufficient data were available for a meta-analysis. The EX groups had modest body weight and FFM changes. Eighty-one percent and 39% of the ER and ER+EX groups, respectively, lost ≥ 15% of body weight as FFM. These findings suggest that exercise is an effective tool to help men and postmenopausal women aged ≥ 50 years, with a BMI greater than 25 kg/m² preserve FFM after moderate ER-induced weight loss, which is important for combating sarcopenic obesity.

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INTRODUCTION

In normal aging, changes in body composition occur that result in a shift toward decreased muscle mass and increased fat mass.1,2 The loss of muscle mass that occurs with aging is termed sarcopenia, and is an important cause of frailty, disability, and loss of independence in older adults.3 It is estimated that sarcopenia costs the United States over $18 billion per year in healthcare expenditures.4 In addition to reduced muscle mass, many older persons experience gains in fat mass. In 2010, the prevalence of obesity among adults aged 60 years and older is estimated to reach 37.4%, which reflects an increase from 32% reported in 2000.5 The coexistence of diminished muscle mass and increased fat mass is referred to as sarcopenic obesity.6 Sarcopenic obesity presents a complex challenge to healthcare professionals who need to prescribe an appropriate treatment that reduces the health risks associated with obesity, such as heart disease and diabetes, while preserving muscle mass to reduce the risk of disability.

Previous research has demonstrated that older adults with sarcopenic obesity have reduced percentages of body weight as fat-free mass (FFM), poorer muscle quality, and poorer physical functioning.6 As a result, the appropriate clinical approach to the treatment of obesity in older persons is controversial due to the potential harmful effects of weight loss on FFM, especially muscle and bone. Diet-induced weight loss results in both a decrease in fat mass and FFM with approximately 75% of weight loss composed of fat tissue and approximately 25% composed of FFM.7,8 Thus, weight loss in older persons could exacerbate the age-related loss in muscle mass and further impair physical function. A 1995 meta-analysis using...
mainly data from studies conducted in young and middle-aged adults revealed that exercise reduced the percentage of weight lost as FFM from approximately 25% to 12%.9 The ability of exercise to preserve FFM in dieting obese older adults has not been evaluated comprehensively. Therefore, the purpose of this systematic review is to evaluate the effects of weight loss induced via energy restriction alone, energy restriction combined with exercise, and exercise alone on FFM in overweight and obese middle-aged and older adults.

**LITERATURE SEARCH**

**Data source**

PubMed was searched for articles published from 1950 to March 30, 2009, using the keywords “weight loss or energy restriction” AND “skeletal muscle or body composition.” The limitations “human” and “middle-aged and aged (>45 y)” were applied to the search parameters.

**Study selection**

In order to effectively evaluate the influence of intentional weight loss on FFM in older, overweight or obese adults, we limited this search to randomized control trials and quasi-experimental designs that sought to induce weight loss via energy restriction, energy restriction combined with exercise, or exercise alone. English-language studies were included if the following subject characteristics were met: mean age >50 years, mean BMI > 25 kg/m², healthy (non-smoker, non-diabetic), and all females were post-menopausal. Acceptable methods of body composition assessment included dual energy X-ray absorptiometry (DXA), air-displacement plethysmography, hydrostatic weighing, and total body potassium. Doubly labeled water was also acceptable; however, none of the accepted studies employed this method. These methods were chosen as they are considered to be highly reliable and valid for detecting changes in FFM in older, overweight and obese adults during weight loss.10-14 Studies that used skin folds to estimate FFM were excluded since the method is less accurate and reliable for assessing body composition in older obese individuals.15 Studies that used bioelectrical impedance were also excluded as a systematic overestimation of lean mass is often seen in older, heavier subjects, and results can vary largely depending on the BIA equation used in different populations.16

**Data synthesis**

A total of 1,819 articles were retrieved during the search and 100 were identified as relevant (Figure 1). Of the 100 relevant articles, 33 were excluded for the following reasons: mean age <50 years; mean age not reported; age range too large (i.e., 18–60 y); no menopausal status was given or women were not postmenopausal; or no FFM measure was reported. One additional article was identified from the references of the 100 relevant articles and it was included.17 Two recent articles were also added manually: One of these articles met all the criteria but was erroneously excluded from the 1,819 articles when the search limits were applied18; the other article was in press and not available through PubMed at the time the literature search was conducted.19 Due to the strong relevance of these articles, they were included in the review. Thus, a total of 70 articles were selected for inclusion; however, 12 of them were later excluded for the following reasons: the subject population had osteoarthritis20 or a mean BMI <25 kg/m²,21 the intervention was less than 6 weeks duration,22-24 or the data reported were already given in a previous (“parent”) manuscript.25-31 Six additional articles were excluded because the interventions employed very-low-energy diets (≤800 kcal/day)25-37; these are not recommended for elderly individuals as they increase the risk for medical complications, the potential for nutrient inadequacy and fluid and electrolyte imbalances, and they accelerate losses of FFM.38

For the final analysis, a total of 52 articles met all the established criteria. (These articles are described in detail in Supporting Information available online.) The articles were separated into the following four categories based on subjects exposed to specific interventions: energy restriction only (Supporting Information Table S1a), energy restriction combined with exercise (Supporting Information Table S1b), exercise only (Supporting Information Table S1c), and studies in which multiple intervention groups were employed to induce weight loss via energy restriction, energy restriction with exercise, and/or exercise (Supporting Information Table S1d).

Five of the final 52 articles included subjects who were hyperinsulinemic17 or who had impaired glucose tolerance,18-42 and one study included hypertensive subjects.43 For 4 of the 52 articles, results from one of the two study groups are not reported here because the subjects in that group were either young,44 taking a supplement for which interactions with mechanisms of muscle metabolism are unknown,45 or had a mean BMI < 25 kg/m².46,47 FFM was estimated by subtracting the amount of body fat from total body weight in one study.46 Twelve studies included control groups and these data were included in the analyses (Supporting Information Table S1a–d) (Figure 2).

**Interventions**

The energy restriction and exercise prescriptions employed in the interventions varied across studies and
Figure 1  **Schematic of the systematic selection process to identify relevant studies.** Abbreviations: VLCD, very-low-calorie diet; BC, body composition.

Figure 2  **Change in FFM in the control groups.** No treatment was prescribed to the control groups and they were told to continue with their normal dietary habits and daily activities. The data are plotted in descending order from largest to smallest loss in body weight. Data presented as mean (+ ± SD when applicable).
lasted between 9 and 52 weeks (Supporting Information Table S1a–d). All food and beverages were provided to the subjects in three studies,14,19,42 while seven studies provided a portion of the food and beverages to be consumed.17,18,48–52 The remaining studies utilized a counseled feeding approach employing a registered dietitian, or a designated laboratory employee (n = 6) to oversee the counseling. Of the studies that included exercise in the intervention, all included aerobic exercise, except for three that included resistance training and five that included both aerobic exercise and resistance training.

Calculations

Many of the studies did not provide values for raw mean change and/or the variance of change for body weight and FFM, so we were unable to calculate average weighted mean differences between pre- and post-intervention values and perform statistical analyses. As a result, we are limited to reporting descriptive results rather than results from a meta-analysis. The data in this review are presented as an estimated mean change from the available data. If the variance was provided in the publication, the data are presented as mean change ± SD.

In Table 1, the mean and percent changes in body weight and FFM, and the percentage of body weight lost as FFM were categorized according to the different magnitudes of change for the three interventions. Each number in Table 1 represents a study group, not an individual subject, and each group varies in size. In addition, dependence exists between groups due to the fact that some groups came from the same study (e.g., one study may have an energy restriction-only group and an exercise-only group). Due to the fact that the study groups cannot be considered to be equally weighted and because there is dependence between some of the groups, the data in Table 1 do not meet the assumptions of statistical tests (i.e., chi-square or Fisher’s exact test). Therefore, we chose to present the results of the studies using defined categories. The changes in body weight were given as absolute changes (≥10 kg loss, <10 to ≥5 kg loss, and <5 kg loss) and percent changes (≥10% loss, <10 to ≥5% loss, and <5% loss). These ranges were based on well-established evidence that body-weight losses of 5–10 kg or 5–10% result in clinically improved fasting glycemia, glycosylated hemoglobin (HbA1c), systolic and diastolic blood pressure, and plasma lipid profile.53–55 Changes in FFM were arbitrarily categorized, and the percentage of body weight

<table>
<thead>
<tr>
<th>Amount of change in body weight or FFM</th>
<th>Energy restriction, % of groups (# of groups)</th>
<th>Energy restriction + exercise, % of groups (# of groups)</th>
<th>Exercise, % of groups (# of groups)</th>
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<tbody>
<tr>
<td>Total number of groups*:</td>
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<td>36</td>
<td>16</td>
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<tr>
<td>Δ Body weight (kg)</td>
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<tr>
<td>≥10 kg loss</td>
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<td>&lt;10 to ≥5 kg loss</td>
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<td>67 (24)</td>
<td>6 (1)</td>
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<td>6 (2)</td>
<td>11 (4)</td>
<td>94 (15)</td>
</tr>
<tr>
<td>Δ FFM (kg)</td>
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</tr>
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<td>19 (7)</td>
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</tr>
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<td>56 (20)</td>
<td>8 (3)</td>
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<td>75 (12)</td>
</tr>
<tr>
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<td>3 (1)</td>
<td>14 (5)</td>
<td>25 (4)</td>
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<td>94 (15)</td>
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<tr>
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<tr>
<td>&lt;0 (gain)</td>
<td>3 (1)</td>
<td>14 (5)</td>
<td>25 (4)</td>
</tr>
</tbody>
</table>

* Each study group is composed of a different sample size.
† The methods for energy restriction and exercise varied across groups; some studies have contributed more than one group.
‡ Percent change in FFM could not be calculated in one study; thus, the number of interventions were reduced by one for energy restriction (n = 35) and energy restriction + exercise (n = 35).
lost as FFM was categorized based on the previous findings in young and middle-aged adults, demonstrating that the addition of exercise to energy restriction attenuated the percentage of weight lost as FFM from 25% to 12%.9

To evaluate trends between the amount of body weight lost and changes in FFM, the data were plotted vertically from the smallest to the largest loss in body weight on the y-axis, starting with the least amount of body weight lost at the bottom and leading to the greatest amount of body weight lost at the top (Figures 2 and 3a,b–5a,b). When the mean change and variance of the change were provided in the source publication, error bars were added to the data point (Figures 2 and 3a,b–5a,b). The absence of error bars in the figures indicates the mean change was estimated.

**EFFECT OF ENERGY RESTRICTION WITH AND WITHOUT EXERCISE ON FAT-FREE MASS**

Among the groups in the energy restriction interventions, 75% had an absolute loss of body weight of between <10 and ≥5 kg. When expressed as a percentage of body-weight loss, this corresponds with 61% of the groups experiencing between <10 and ≥5% loss of body weight (Table 1). Energy restriction also resulted in a FFM loss of between <3 and ≥1.5 kg in 56% of the groups (Table 1). When evaluating the composition of the body weight lost, one-half of the groups lost ≥25% of their body weight as FFM (Table 1); this is comparable to previously reported diet-induced FFM changes in younger and middle-aged adults.9
The addition of exercise to energy restriction resulted in an attenuated loss of FFM (Table 1). Fifty-six percent of the energy restriction with exercise groups lost between <1.5 and >0 kg FFM compared to 22% in the energy restriction groups, and 47% lost between <15 and 0% of their body weight as FFM. The changes in body weight in these groups were similar to those in the energy restriction-only groups when expressed as either absolute change (67% with <10–±5 kg) or percent change in body weight (69% <10–±5%; Table 1). In the articles included in this review, few authors reported mean change (pre- to post-intervention) values and the variance of the change. Consequently, we were unable to calculate a weighted mean average for the percentage of weight lost as FFM. If this value is crudely estimated from the available data, the findings suggest that the addition of exercise to energy restriction reduces the amount of weight lost as FFM from approximately 24% to approximately 11%. These results extend findings in young and middle-aged adults in which the addition of exercise to energy restriction is documented to attenuate the percentage of weight lost as FFM from 25% to 12%.^9^ Collectively, the present findings demonstrate that the addition of exercise to energy restriction is effective in preserving FFM in older adults.

During the first 6 months of energy restriction, the rate of weight loss is fairly linear.56,57 The proportion of body fat mass and FFM loss is often assumed to remain constant; however, the rate of weight loss may affect the composition of the weight loss.14 An accurate assessment

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**Figure 4.** Changes in FFM following energy restriction combined with exercise. Data are plotted in descending order from largest to smallest loss in body weight for (a) absolute change in FFM and (b) percent of weight loss as FFM ([Δ FFM/Δ body weight] × 100 = % weight loss as FFM). Indicates resistance exercise was prescribed in the intervention. Data presented as mean (±SD when applicable).
of this relationship would require a study that evaluated the time course of body composition changes by measuring body weight and composition at frequent intervals (e.g., weekly). To our knowledge, this type of study has not been performed and most of the studies in this review measured body composition pre- and post-intervention only. As a result, it is difficult to examine the relationship between the rate of body-weight loss and changes in FFM in these older adults. Quantitatively, the results show that the magnitude of body weight lost did not influence the total amount of FFM lost and the percentage of body weight lost as FFM in the energy restriction-only groups (Figure 3a-b). Similarly, the magnitude of weight lost does not appear to influence changes in FFM following energy restriction with exercise (Figure 4a-b). A preservation of FFM with exercise is further demonstrated by a rightward shift in both the absolute change in FFM (Figure 4a) and the percentage of body weight lost as FFM (Figure 4b) compared to the energy restriction-only groups (Figure 3a-b).

EFFECT OF EXERCISE ON BODY WEIGHT AND FAT-FREE MASS

Exercise is generally considered to be less effective as a weight-loss strategy when energy restriction is not included. Nonetheless, it was felt that the inclusion of studies that induced weight loss via exercise only would help elucidate the independent and synergistic effects of energy restriction and exercise on FFM in obese older adults. As expected, the exercise-only groups in this review lost less body weight compared to the energy restriction and energy restriction plus exercise groups, with 94% losing <5kg and <5% body weight (Table 1). These findings are comparable with those of previous studies that reported approximately 0.45% loss in body weight following 12 weeks of exercise and 2.1kg loss in body weight following 6 months of exercise. In addition to losing the least amount of body weight, individuals in the exercise-only interventions lost the least amount of FFM. Seventy-five percent of the groups lost <1.5 to 0kg and 15% experienced a gain in FFM mass (Table 1). Only one of the 16 groups that induced weight loss with exercise included resistance training in the intervention, and this group experienced a gain in FFM (Figure 5a). This finding is not surprising given that resistance exercise is a well-established stimulus for muscle growth and maintenance in younger and older adults. Interestingly, the aerobic exercise groups were able to successfully preserve FFM (Figure 4a-b), which suggests that weight loss induced by aerobic exercise is an effective intervention for the maintenance of FFM. However, the success of aerobic exercise for preserving FFM is likely a result of these groups losing less body weight overall.

Figure 5 Changes in FFM following exercise. Data are plotted in descending order from largest to smallest loss in body weight for (a) absolute change in FFM and (b) percent of weight loss as FFM [(ΔFFM/Δ body weight) × 100 = % weight loss as FFM]. indicates resistance exercise was prescribed in the intervention. Data presented as mean (± SD when applicable). *Lambert et al. reported a mean gain in FFM and small loss in body weight resulting in 533% of weight lost as FFM.
CHANGES IN FAT-FREE MASS VERSUS CHANGES IN SKELETAL MUSCLE

In this review, acceptable methods for measuring FFM included DXA, air-displacement plethysmography, hydrostatic weighing, or total body potassium. These methods are highly reliable and valid for detecting changes in FFM. However, it is important to consider whether or not changes in whole-body FFM reflect changes in skeletal muscle. Computed tomography and magnetic resonance imaging are excellent tools to accurately measure skeletal muscle mass, but the high cost of these measures limits their use to research, and not clinical and community settings.

A good correlation exists between DXA-derived appendicular lean soft tissue and computed tomography and magnetic resonance imaging-derived skeletal muscle mass from the lower limb in younger and older adults. Three studies in this review measured appendicular lean soft tissue in addition to total FFM. In the energy restriction interventions, 4.6% of FFM was lost and approximately 5.2% of appendicular lean soft tissue was lost. In the exercise intervention, 6.8% of FFM was lost and approximately 7.7% of appendicular lean soft tissue was lost. Together, these data suggest that during energy restriction with and without exercise, changes in whole-body FFM are comparable to changes in appendicular lean soft tissue in older, overweight and obese adults.

Additionally, three studies in this review included magnetic resonance imaging and total FFM measurements, and one study, which was excluded because the DXA data were already in a previous "parent" manuscript, also provided magnetic resonance imaging data in addition to total FFM measurements. Losses of approximately 2.9% in FFM and approximately 0.9% in the mid-thigh cross-sectional area following energy restriction were reported, while an FFM loss of approximately 2.3% and an approximately 0.5% gain in mid-thigh cross-sectional area was reported following exercise (data not shown). Changes in measurements of the mid-thigh cross-sectional area appear to be less comparable to changes in whole-body FFM, as opposed to changes in appendicular lean soft tissue, which seem to match whole-body FFM changes.

The discrepancies between changes in whole-body FFM and skeletal muscle may be accounted for by the composition of the FFM lost (i.e., water, protein, and mineral masses). One study in this review evaluated the composition of FFM changes in older women before and after a 12-week, 500 kcal/day energy deficit with and without resistance training. Following the intervention, the women lost 1.6 and 2.1 kg in FFM and total body water, respectively, but no changes were detected in protein-mineral mass. When the women performed resistance exercise training during the energy restriction intervention, there was no change in FFM, total body water, or protein-mineral mass. These data demonstrate that the loss in FFM following moderate energy restriction, as well as the preservation of FFM following resistance training, are primarily due to changes in body water. It is important to note that the resistance-trained women increased their muscle strength following the 12 weeks whereas the sedentary women maintained strength. This suggests that hydration status may be important for muscle mass and function. Both groups maintained euhydration (urinary specific gravity within range of adequacy), despite a decline in total body water in the energy restriction-only group. Further research is needed that utilizes measurements of muscle hydration and function to better evaluate the influence of the loss in total body water on muscle function in older dieting men and women.

SARCOPENIC OBESITY AND PHYSICAL FRILTY

Research has previously focused separately on the roles of obesity and sarcopenia in physical functioning and disability; however, over the past few years, cross-sectional evaluations have offered insight into the relationship between sarcopenic obesity and physical function. Baumgartner et al. reported that men with sarcopenic obesity had an odds ratio of 8.72 for two or more self-reported physical disabilities with Instrumental Activities of Daily Living, compared to 3.78 for sarcopenia and 1.34 for obesity. Similarly, sarcopenic obese women had corresponding odds ratios of 11.98, 2.96, and 2.15, respectively. These findings suggest that obesity in older adults may act synergistically with sarcopenia to increase functional impairment.

A more recent cross-sectional evaluation examined the relationship between FFM and physical functioning in three groups of older adults: obese, non-obese frail, and non-obese non-frail. The results revealed that the average FFM in the lower extremities of the obese group was significantly higher (8.5 ± 4.0 kg; mean ± SE) compared to their non-obese frail (7.0 ± 2.5 kg) and non-obese non-frail (6.5 ± 2.0 kg) counterparts. Despite having a higher absolute quantity of FFM, the percentage of body weight as FFM and muscle quality (force per unit of cross-sectional muscle area) was lower in the obese adults. Furthermore, the obese group had scores that were equal to or lower than those of the non-obese non-frail group in the physical performance test, peak aerobic power, and the functional status questionnaire. Similar impairments were seen in strength, walking speed, balance, and health-related quality of life. Slightly overweight older adults (BMI 25–30 kg/m^2) are thought to be protected from disability as a lower body mass index is
often associated with disability. These results demonstrate that obese older adults exhibit physical frailty and underscore the need for an intervention to improve physical function in this population.

A progressive exercise program that includes flexibility, endurance, and strength training is thought to minimize FFM loss, improve physical function, and ameliorate frailty in old and frail adults. However, little data exists on the effect of intentional weight loss and exercise on physical frailty in obese older adults, and to date, only one randomized control trial has examined changes in physical function in this population with weight loss. Following a 6-month diet (750 kcal/day energy deficit) coupled with an exercise intervention that included 3 days per week of flexibility, strength, endurance and balance training, the authors reported that an 8.5% decrease in body weight resulted in no change in FFM compared to the control group. Furthermore, the treatment group improved in a variety of physical function tests, as well as strength, gait, and balance tests. The authors concluded that weight loss and exercise can ameliorate frailty in obese older adults. Further studies are needed to evaluate the reproducibility of these findings and to better understand the impact of weight loss and exercise on physical outcomes in obese older adults.

SEX DIFFERENCES IN WEIGHT LOSS-INDUCED CHANGES IN FFM

Few studies in this review were statistically powered to assess the effect of sex on changes in body weight and FFM. Far more women were studied than men in the interventions, and the physiological responses to energy restriction and exercise may be different between men and women as they experience different hormonal changes with aging (i.e., menopause, somatopause, and andropause). During this time there are drastic reductions in sex steroids such as estrogen, growth hormone, or testosterone, all of which can influence FFM. Furthermore, previous research has demonstrated that older men experience a greater absolute and relative increase in knee extensor muscle volume compared to women after 9 weeks of progressive resistance training. The extent to which sex interacts with energy restriction and exercise to influence FFM in older adults is currently not fully understood.

RECOMMENDATIONS

Sarcopenic obesity in older adults has important functional implications, as obesity may exacerbate the age-related decline in physical function and, when combined with sarcopenia, lead to frailty. The appropriate treatment for obesity in older adults should aim to reduce body fat while minimizing muscle and bone losses and maintaining or improving physical function.

Energy restriction

The position statement on obesity in older adults by the American Society of Nutrition and the Obesity Society provides two ranges of daily energy deficits for a weight-loss regimen. A 500–1,000 kcal/day reduction is given as a treatment guideline to achieve a weight loss of approximately 0.4–0.9 kg (1–2 lb)/week, while a modest reduction in energy intake of 500–750 kcal/day is provided as a recommendation. In this review, 60% of the studies prescribed a modest energy restriction (energy intake >1,300 kcal/day or <500 kcal/day energy deficit), while the other 40% prescribed a more moderate restriction (energy intake 900–1,300 kcal/day or 500–800 kcal/day energy deficit). Despite the statistical limitations, the qualitative data in Figures 3a,b and 4a,b suggest that the magnitude of body weight loss does not influence changes in FFM. When comparing the data in this review to the current recommendations, the present findings suggest that energy restrictions both below (approximately 250 kcal/day energy deficit) and within (750 kcal/day energy deficit) the recommended ranges would have similar influences on the overall change in FFM. However, caution is advised when regarding these results because they are descriptive and not statistically evaluated.

Exercise

The American College of Sports Medicine and the American Heart Association recommend 30–60 min/day (150–300 min/week) of moderate-intensity aerobic activities, ≥2 days/week of moderate-to-vigorous resistance exercise training, and flexibility exercises ≥2 day/week for all older adults, regardless of obesity status. The American Society of Nutrition and the Obesity Society do not give specific guidelines in their position statement on obesity in older adults, but they state that an exercise program that includes stretching, aerobic activity, and strength exercises is recommended to increase flexibility, endurance, and strength. The overall goal of these recommendations is to harness the positive metabolic benefits of exercise for the prevention, management, and treatment of diseases as well as for the maintenance or improvement of functional capacity. Exercise as a sole means of weight loss is generally not included in these recommendations. This is likely due to findings demonstrating that exercise is less effective as a weight-loss strategy when energy restriction is not included. The results of the present review support these findings, as weight loss
induced via exercise alone results in a modest weight loss (94% of groups lost <5 kg). The addition of exercise to the energy restriction intervention did not result in a greater loss in body weight, but it did demonstrate an attenuation of the amount of FFM lost. Since a majority of the interventions that included exercise in this review used aerobic exercises, the findings are mostly applicable to aerobic exercise. Studies in obese older adults that induce energy restriction and prescribe only resistance training (with a measure of FFM) are sparse. Given that resistance exercise is a potent stimulus of muscle hypertrophy, even in older adults, it would not be surprising if the addition of resistance training to a weight-loss program were to preserve FFM to a greater extent than aerobic exercise alone. Whether or not aerobic exercise in conjunction with resistance training during a weight-loss program would have a synergistic effect on the preservation of FFM is not clear. Nonetheless, it is apparent that the addition of exercise to a weight-loss program be it aerobic, resistance, or both, can preserve FFM in obese middle-aged and older adults.

CONCLUSION

In summary, energy restriction alone appears to be successful for producing a moderate loss in body weight, but this success can be costly in terms of losses in FFM. The addition of exercise to energy restriction does not appear to have an additive effect on the amount of weight lost, but it can attenuate the loss of FFM. Exercise alone leads to small losses of both body weight and FFM. Thus, if the goal is to reduce body weight without largely compromising FFM, energy restriction with exercise would be an appropriate recommendation. If the maintenance of FFM is the primary concern, then exercise alone would suffice. Ultimately, the appropriate intervention will need to be determined on an individual basis as the current health status of the individual will likely dictate the desired outcome.

Because physical frailty is common in sarcopenic obese adults, future studies that include direct measures of skeletal muscle size (i.e., computed tomography or magnetic resonance imaging) in combination with functional outcomes following weight loss are warranted. In addition, data that evaluate the influence of different exercise modes, such as aerobic or resistance exercise or both, on FFM during weight loss are lacking. These findings would strengthen the literature and provide further insight into the independent and synergistic effects of energy restriction and exercise on FFM in dieting older adults.

The opportunity to evaluate the influence of the recommended daily energy deficits and exercise prescriptions on changes in FFM was negated because many of the articles did not include complete data sets (i.e., the mean and variance for pre, post, and change values). As studies continue to investigate the appropriate treatment for obesity in older adults, the publication of complete data sets will provide information to allow future systematic reviews and meta-analyses to more accurately and quantitatively report the findings, hence, allowing the medical community to make more appropriate recommendations.

The prevalence of obesity in older adults is increasing, and sarcopenic obesity presents a complex issue to healthcare professionals who need to comprehensively evaluate the risks and benefits of weight loss in an older individual before prescribing a treatment. Current evidence suggests that a modest to moderate energy restriction coupled with exercise is an effective means for older overweight and obese adults to counter sarcopenic obesity while blunting compromises in FFM.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table S1 (a) Study interventions inducing weight loss in older adults via energy restriction only; (b) Study interventions inducing weight loss in older adults via energy restriction combined with exercise; (c) Study interventions inducing weight loss in older adults via exercise only; (d) Studies in which multiple intervention groups were employed in each study to induce weight loss in older adults. Interventions included energy restriction, exercise, and/or energy restriction combined with exercise.

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