Received: 13 October 2018 | Accepted: 5 November 2018

DOI: 10.1111/obr.12815

WILEY obesityreviews

Treatment of obesity in older persons—A systematic review

Cilla Haywood[1,2,3] | Priya Sumithran[1,2]

[1] Department of Medicine (Austin Health), University of Melbourne, Heidelberg, Victoria, Australia

[2] Department of Endocrinology, Austin Health, Heidelberg, Victoria, Australia

[3] Department of Aged Care, Austin Health, Heidelberg, Victoria, Australia

Correspondence
Dr Priya Sumithran, Heidelberg Repatriation Hospital, 300 Waterdale Road, Heidelberg Heights, VIC 3081 Australia.
Email: priyas@unimelb.edu.au

Summary

The study aims to systematically review the available evidence regarding weight loss interventions (lifestyle, surgical, and pharmacological) for obesity in adults aged over 60 years. A search of prospective, randomized studies took place in January 2018, on Medline (Web of Science) and PubMed databases. Search terms included the following: elderly, obese, hypocaloric, pharmacotherapy, and bariatric surgery. Abstracts were screened for eligibility. A total of 256 publications regarding lifestyle interventions were identified; of these, 69 studies were eligible. As no eligible studies were identified for pharmacotherapy or bariatric surgery, the search was broadened to include non- randomized studies. Four pharmacotherapy and 66 surgery studies were included. Lifestyle intervention had similar weight loss efficacy in older compared with younger people, with positive effects on a number of relevant outcomes, including physical function and cardiovascular parameters. There was little data regarding obesity pharmacotherapy in older persons. The available data for bariatric surgery indicate comparable weight loss and resolution of type 2 diabetes, with similar or slightly higher complication rates in older compared with younger people. Older age alone should not be considered a contraindication to intensive lifestyle or surgical intervention for obesity. There are insufficient data to guide clinical decisions regarding obesity pharmacotherapy in older people.

KEYWORDS

aged, bariatric surgery, medications, obesity, reducing diet

1 | INTRODUCTION

The prevalence of obesity has increased rapidly in the last 40 years, particularly among adults aged 60 to 74 years.[1] The presence of obesity in older adults is associated with disability and worsening of chronic diseases including type 2 diabetes, cardiovascular disease, and osteoarthritis.[2] The inflammatory milieu of obesity and the metabolic syndrome also occurs in diseases of ageing such as sarcopenia, frailty, and dementia; hence, these two sets of conditions potentiate each other.[3-6]

Excess weight gain and adiposity-related complications develop through an interaction of environmental and genetic factors, rather than resulting from a person's lack of willpower.[7] A change in diet and/or physical activity to induce a negative energy balance brings about compensatory changes in adipocyte and gut hormones, energy expenditure, and appetite and brain responses to food, making maintenance of weight loss difficult.[8-10] Recent guidelines for treatment of obesity support consideration of intensive interventions, such as very-low-energy diets (VLEDs), pharmacotherapy, and bariatric surgery, as adjuncts to lifestyle and behaviour modification in selected patients, to assist loss of weight and maintenance of weight loss.[11,12]

Despite the increasing prevalence of obesity in older adults, weight loss interventions in this group have been considered controversial due to concerns about whether they might increase mortality, or accelerate the sarcopenia associated with ageing.[13] Furthermore, older adults are more likely to be affected by polypharmacy and cardiovascular disease, which may increase the risks of appetite-reducing pharmacotherapy and bariatric surgery.

A previous review summarized randomized, controlled weight loss intervention studies in the elderly published as of 2010.[14] Since

then, four pharmacological agents/combinations have been approved by the US Food and Drug Administration (FDA) for treatment of obesity, and the profile of bariatric surgery has changed, with sleeve gastrectomy increasingly commonly performed.[15]The aim of this review is to examine current evidence for the efficacy and safety of medical and surgical treatment of obesity in older (≥60 years) adults.

2 | METHODS

The review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[16]

2.1 | Types of studies and eligibility criteria

Studies were considered eligible if they examined the efficacy and/or safety of weight loss interventions, comprising behavioural/lifestyle, VLEDs, pharmacotherapy, or bariatric surgery, in people with obesity (body mass index [BMI] ≥30 kg/m^2), and either (a) included only older adults (≥60 years), (b) reported study results for adults ≥60 years separately, or (c) the mean age of participants was ≥60 years.

For behavioural/lifestyle and diet interventions, only prospective, randomized controlled trials (RCTs) were evaluated.

No eligible RCTs were identified for pharmacotherapy or bariatric surgery; therefore, in order to assess the available evidence in this population, studies that were not randomized and/or controlled were also screened for possible inclusion if they focused on older adults and reported results for weight outcome and/or adverse events.

2.2 | Search methods

2.2.1 | Sources

Medline (Web of Science) and PubMed were searched on January 11, 2018, for articles published from database inception to the current date, using a combination of search terms related to obesity, older adults, and weight loss interventions. Reference lists of retrieved articles and key systematic reviews were also searched for additional potentially eligible papers. An example of the search strategy is shown in Table 1.

TABLE 1 Example of search strategy

#4	**Search (#1 AND #2 AND #3)**
#3	Search ((((low calorie diet [Title/Abstract]) OR hypocaloric [Title/Abstract]) OR weight loss intervention [Title/Abstract]) OR behavioural intervention [Title/Abstract]) OR behavioral intervention [Title/Abstract]
#2	Search (randomised [Title/Abstract] OR randomized [Title/Abstract] OR RCT [Title/Abstract] OR randomly [Title/Abstract] OR random [Title/Abstract])
#1	Search ((obesity [Title/Abstract] OR obese [Title/Abstract] OR "weight loss"[Title/Abstract] OR "weight reduction"[Title/Abstract])) AND (elderly [Title/Abstract] OR older [Title/Abstract] OR geriatric [Title/Abstract])

2.2.2 | Study selection

Identified articles were manually screened for possible eligibility based on title and abstract. Full-text screening of potentially relevant articles was done by both authors to identify studies for inclusion, and disagreements resolved by consensus. Data were extracted into a template, including the following: number and age of participants, details of interventions, outcome measures, and adverse events.

2.2.3 | Assessment of risk of bias

The Cochrane tool for assessing risk of bias in RCTs,[17] and the Transparent Reporting of Evaluations with Non-randomized Designs (TREND) checklist[18] for non-randomized studies were used to assess potential risk of bias across domains including selection, performance, attrition, reporting, and other biases.

3 | RESULTS

3.1 | Search results

3.1.1 | Lifestyle/behavioural/VLED interventions

The initial search identified 254 publications, and 81 met the criteria for the review on the basis of the abstract. A further two articles were identified as associated studies (ie, separate publication from the same study). After full-text review, 69 publications were included in the final review (Figure 1).

3.1.2 | Pharmacotherapy

An initial search for RCTs identified 49 studies, of which after removal of duplicates, 32 abstracts were screened, and four were eligible for full-text review. None of the four remained eligible for inclusion (outcomes for older adults not reported n = 2; no pharmacotherapy n = 1, mean age in older group <60 years n = 1). The search was then broadened to include non-randomized studies, and 167 studies were identified, of which 76 abstracts were screened after removal of duplicates. Sixty-eight studies were not eligible for inclusion, leaving eight studies of which the full text was reviewed, and four which were included (Figure S1 in supplementary information).

3.1.3 | Bariatric surgery

An initial search for RCTs identified 41 studies, of which after removal of duplicates, 24 abstracts were screened, and none were eligible for full-text review. When the search was broadened to include non-randomized studies, 729 studies were identified, of which 412 abstracts were screened after removal of duplicates, the full text of 92 studies was reviewed, and 66 studies were included (Figure S2).

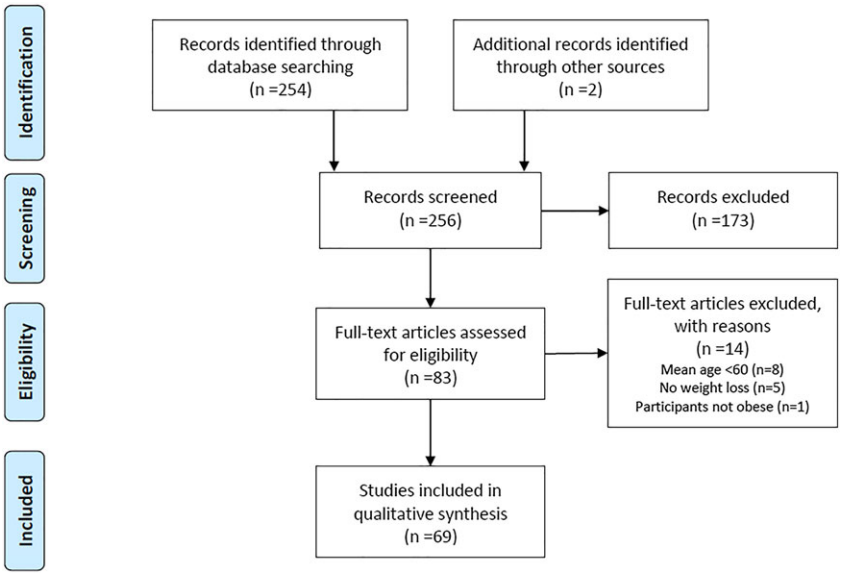


FIGURE 1 Overview of study search and selection for randomized controlled trials (RCTs) of lifestyle interventions [Colour figure can be viewed at wileyonlinelibrary.com]

3.2 | Characteristics and risk of bias of included studies

3.2.1 | Lifestyle/behavioural intervention/VLED

Since the early 2000s, there have been numerous studies examining the effects of intentional weight loss in older adults, examining domains including physical function, quality of life, body composition, cardiovascular and glycaemic markers, cognition, inflammatory markers, and sex hormones. Some have prospectively examined effects on mortality. One has analysed the cost compared with benefits of intervention. The results are shown in Table S1, and outlined below, broken down by end point.

Randomized controlled studies of lifestyle intervention were assessed for risk of bias using the method described by the Cochrane Collaboration,[17] categorizing the risk across different domains as low, medium, high, or unclear (ie, not clearly documented). Table S4 summarizes the risk of bias in lifestyle intervention RCTs. Many of the included publications reported different end points of large trials, eg, Comprehensive Lifestyle Intervention Programme (CLIP)[19]; Arthritis, Diet, and Activity Promotion (ADAPT)[20]; Intensive Diet and Exercise for Arthritis (IDEA)[21]; Physical Activity, Inflammation, and Body Composition Trial (PACT)[22]; and a trial by Villareal et al,[23] and these larger studies had minimal bias. The risk of bias was generally low with most of the smaller studies also.

3.2.2 | Pharmacotherapy

The four pharmacotherapy studies included were from single centres in the United States, Brazil, Italy, and Turkey. One described the pharmacokinetics of a single dose of lorcaserin 10 mg in 12 elderly people (mean age 68 years) compared with a younger control group.[24] The remaining three papers did not include a control group. As such, the quality of evidence regarding safety and efficacy of pharmacotherapy is weak. Horie and colleagues reported the experience of 51 patients aged 60 to 79 years treated in an outpatient obesity clinic in Brazil, with at least 6 months' follow-up.[25] Of the numerous medications used in the clinic (Table S2), only orlistat is widely approved (including in the United States, European Union, and Australia) for treatment of obesity. Varli et al examined the effect of weight loss over 6 months with a low calorie diet and orlistat on cardiac Doppler parameters in 13 older women,[26] and the remaining study was a prospective case series of nine patients aged 65 to 75 years with type 2 diabetes who were treated with liraglutide 3.0 mg for 24 weeks.[27]

3.2.3 | Bariatric surgery

Characteristics of the included studies are shown in Table S3. The majority were retrospective case series descriptions from single centres, primarily in the United States, with others from Australia, Brazil, Canada, and Europe, which reported on more than 20 000 patients aged between 60 and 83 years who underwent surgery. Laparoscopic adjustable gastric banding (LAGB), sleeve gastrectomy, and Roux-en-Y gastric bypass (RYGB) were the most common operations, and the majority of studies had follow-up durations of at least 1 year (up to 8 years). Due to the nature of the intervention, no studies involved blinding of participants or investigators. Ten studies evaluated only the safety of bariatric surgery,[28-37] and the remainder evaluated weight loss efficacy as well as safety, although the reported measures of efficacy and safety varied between studies. Thirty-nine of the 66 included studies compared outcomes between older adults and a younger group,[28-31,33-35,37-68] and in 12 of these studies,[39,48,50-52,54-56,59,63,64,68] groups were matched for characteristics such as sex, BMI, and surgery type. The remaining studies reported results for older persons without a comparison group.

Figure S3 summarizes the risk of bias in the pharmacotherapy and bariatric surgery studies reviewed.

3.3 | Effects of interventions

3.3.1 | Lifestyle/behavioural intervention/VLED

Weight loss

Overall weight loss efficacy was dependent on the type of diet (balanced hypocaloric versus partial or full meal replacement), and the

duration of the intervention. Participants undergoing full meal replacement with VLEDs, consuming 800 to 1000 kilocalories (kCal) per day, lost between 12% and 15% of their initial body weight over a period of 12 to 24 weeks.[69-71] Use of partial meal replacements and aiming for an energy deficit of 800 to 1000 kCal/d yielded lower weight loss over a longer time; approximately 8% to 10% over 6 to 18 months.[21,22] Many other studies utilized a balanced hypocaloric diet with normal foods, obtaining a 500 to 750 kCal energy deficit per day. This yielded weight losses of between 5% and 10% over 6 to 18 months.[20,23,71-77] The addition of exercise to a hypocaloric diet did not yield significantly greater weight losses than a hypocaloric diet alone.[20,23,74,78] When energy intakes were equal, increasing the protein content above 0.9 g/kg/d[79,80] or changing protein source[81] did not result in any differences in weight or lean mass loss, nor did changing the glycaemic index of the carbohydrates.[82] In studies where older and younger participants were compared in terms of weight loss efficacy on the same diet intervention, older participants lost more weight than younger participants.[83,84] Given the same hypocaloric diet, a higher calorie expenditure exercise regimen led to greater weight losses than lower calorie expenditure exercise.[85]

Long term weight loss maintenance

Weight regain is an issue of concern following intentional weight loss, and a number of studies have explored this in older people. After a follow up of 18 months, two studies have demonstrated weight regain of 40% to 65% of initial weight loss, and this regain was made up of body fat.[86,87] However, one of these studies[86] also followed up physical function, and found that despite weight regain, physical function improvements were maintained. Ongoing counselling with use of an accelerometer[75] and increased water consumption[88] have both been demonstrated to offset weight regain in older persons.

Changes in body composition, bone mineral density, and hormone levels

Many of the larger studies examining weight loss in older persons examined the changes in fat, lean, and bone mass, usually using Dual Energy X-ray Absorptiometry (DXA). Weight loss with calorie restriction reduces fat mass and lean mass.[23,74,77,78,89-92] However, fat mass is lost in greater quantities than lean mass during intentional weight loss, such that the percentage of lean mass after the intervention is increased.[71,81] In studies where changes in body composition were prospectively correlated with changes in physical function, it was demonstrated that improvements in physical function correlated with decreases in fat mass.[89-92]

Intentional weight loss causes bone mineral density to decrease in proportion with the amount of weight loss.[23,78,93-95] With 1 kg loss of weight, there is a decrease in bone mineral density of 0.1% at the femoral neck.[78] Multimodality exercise, incorporating strength, balance, endurance, and flexibility offsets losses in lean mass and bone mass.[23,93,94]

Sex hormones (oestrogen and testosterone) decline with age, and their levels alter with changes in body fat. Levels of the adipokine leptin are proportional to body fat, and adiponectin levels are inversely proportional to body fat. Changes in these hormones during intentional weight loss in older persons have been investigated. In a study examining diet and exercise either alone or combined, versus control, it was demonstrated that men randomized to diet alone, or to diet and exercise combined, had increases in testosterone and decreases in oestradiol. However, improvements in physical function were seen not only in these groups but also in men randomized to exercise alone with no weight loss; hence, changes in these sex hormone levels were unrelated to physical function.[96] In another study, levels of growth hormone were higher in women (but not men) randomized to a dietary intervention than those who were not, but none of the changes in other hormones measured (cortisol, sex hormone-binding globulin, testosterone, and dehydroepiandrosterone) correlated with changes in physical function.[97] Leptin was decreased after a weight loss intervention compared to before weight loss in women only[98]; another small study revealed no change in adiponectin in a weight loss plus exercise group compared with an exercise alone group.[99]

Changes in physical function

Significant overweight in older adults is most problematic because of its association with poorer physical function, disability, and increased risk of residential care admission; hence, the importance of examining the effects of weight loss interventions on physical function. Physical function has most commonly been measured utilizing gait speed, muscle strength by one-repetition maximum, and balance. Exercise regimens varied between studies, but incorporated strength, cardiovascular endurance, or both. Various combinations of diet alone, diet and exercise, exercise alone, and attention controls have been compared. Where diet plus exercise is compared with control, there is a clear and significant improvement in physical function in the treatment group.[76,100] Studies that compared exercise alone with diet and exercise revealed similar improvements in physical function.[77,101,102] Studies comparing diet plus exercise, diet alone, and exercise alone revealed improved self-reported[20] or objective[21,23,103] physical function in the diet plus exercise groups, followed by exercise, diet then control. A single study comparing weight loss with diet and exercise with differing protein intakes revealed improved physical function in the higher protein intake (1.2 g/kg/d versus 0.8 g/kg/d) group.[73]

Cardiovascular and glycaemic outcomes, markers of inflammation

Obesity is a risk factor for hypertension, dyslipidemia, and type 2 diabetes.[104] Weight loss induced by hypocaloric diet and exercise, of the order of 5% to 10%, led to significantly reduced systolic and diastolic blood pressure.[105-107] More modest weight losses of 3% to 4% combined with sodium reduction to 1.8 g/d led to a significant reduction (hazard ratio 0.47 [95% CI, 0.35-0.64]) in a combined end point (requirement for blood pressure medication, hypertension, and cardiovascular event) in older hypertensive study participants with obesity, relative to usual care.[108] Effects on lipid measures were more variable; one study revealed a reduced atherogenic total to high-density lipoprotein (HDL) ratio in the intensive exercise (greater weight loss) arm than the less intensive exercise arm.[85] Another study[107] found that improvements in HDL and glucose metabolism were correlated with weight loss; however, aerobic exercise improved maximal oxygen

uptake (VO_{2max}). Weight loss was associated with reduction in triglycerides.[105,107] Calorie restriction leading to weight loss, exercise, and a combination of both improve insulin sensitivity in older adults with obesity.[109,110] In older adults with heart failure with preserved ejection fraction and obesity, a diet and exercise intervention led to a 10% weight loss over 20 weeks, with improved VO_{2max} which correlated with improvement in lean mass.[111] This improvement in VO_{2max} was superior to either diet or exercise alone. Markers of inflammation such as interleukin 6 (IL-6), tumour necrosis factor alpha (TNF-α), and C-reactive protein (CRP) were generally (but variably) reduced in proportion to weight loss[112-114]; however, one study revealed no absolute change in these biomarkers with weight loss.[115]

Nutritional parameters

It is important that adequate intake of protein, fatty acids, and micronutrients be maintained in the face of caloric restriction, particularly in older adults who have chronic diseases. Where nutritional quality of weight loss diets (including meal replacements) was assessed by food recall diaries, it was found that those randomized to weight loss ate fewer calories and fats (with a higher percentage of carbohydrates); however, the adequacy of micronutrient intake was variable.[116,117] A study comparing VLEDs with hypocaloric balanced diets and healthy eating examined the effects on serum vitamin D, B12, ferritin, albumin, and red cell folate and found that use of a VLED was associated with a significant increase in all of these parameters despite having the greatest caloric deficit.[71]

Quality of life

Weight loss studies examining quality of life found that improvement in quality of life scores correlated with weight decrease[118,119] and gains in strength.[118] Another study found that improvement in quality of life score related to weight loss was limited to physical health domains.[120]

Cognition

In 12-month weight loss studies examining participants with normal cognition[118] and mild cognitive impairment,[121] diet plus exercise and exercise alone was demonstrated to improve scores on global cognitive tests.

Adverse effects

Other than decrements in lean mass, adverse events were not commonly reported, with the exception of those studies examining the use of VLEDs. VLEDs were associated with constipation, dizziness, cold intolerance (all of which are well documented),[70,71] and minor increases in urea and creatinine.[69] Where adverse events were reported, these were related to falls during exercise interventions.[20,23,122] Large weight loss studies, which followed up participants for 7[123] and 9[124] years, found no increase in mortality in those randomized to the weight loss arm compared with those who were not.

Cost-Effectiveness

Only one study has examined the cost-effectiveness of weight loss intervention, and it found that, while the diet plus exercise arm was most expensive, it had the greatest effect on stiffness, pain, and joint function, which are the strongest predictors of downstream health utilization.[125]

3.3.2 | Pharmacotherapy

The examination of the pharmacokinetics of a single dose of lorcaserin 10 mg in 12 elderly people (mean age 68 years) compared with a younger control group concluded that there were no clinically relevant differences in pharmacokinetics and tolerability, and therefore, no dose adjustment was required in older people with normal renal function, although the findings cannot be extrapolated to the recommended dosing of 10 mg bd.[24] Orlistat was used by 11 attendees of an outpatient clinic for a mean of 8.7 ± 5.0 months and resulted in a mean weight loss of 3.3 ± 5.9 kg in the report by Horie et al,[25] and by 13 women for 6 months in the study by Varli et al[26] resulting in a mean weight loss of 8.4 kg (9.4%). All completers (13/18) achieved weight loss of ≥5% at 6 months. In the prospective case series of nine patients aged 65 to 75 years with type 2 diabetes treated with liraglutide 3.0 mg for 24 weeks, median losses of weight and fat mass of 2.0 and 1.5 kg, respectively, were reported.[27]

3.3.3 | Bariatric surgery

Efficacy

Of the 28 studies in which weight outcomes for older and younger persons were compared, 16 found no significant difference in weight loss between groups,[38,40,42-46,48,54,59,61,64-68] and seven studies reported less weight loss in older than younger participants.[39,41,47,50,51,55,62] Greater total weight loss in younger participants but no difference in percent excess weight loss (%EWL) between groups was reported in two studies.[52,63] One study reported no difference in %EWL between groups with LRYGB, but greater %EWL in younger patients after LAGB,[57] while another reported no difference in percent total weight loss (%TWL) after LAGB, but greater %TWL after RYGB and laparoscopic sleeve gastrectomy (LSG) in younger patients.[58] One study reported no difference in total weight loss or %EWL between groups at 1 year, but greater %EWL in younger patients 5 years post-LAGB.[49] No studies found significantly greater weight loss in the older compared with younger group. Studies in which percentage total weight loss (%TWL) was reported in older people found loss of 17% to 38% after 1 to 6 years following gastric bypass and sleeve gastrectomy,[38,40,44,47,50-52,58,61,63-65,68,126-131] and loss of 14% to 20% after adjustable gastric banding.[58,132,133] For studies in which weight outcome was reported as percentage excess weight loss (%EWL), older persons undergoing RYGB or LSG lost 46% to 77% excess weight at 12 to 21 months,[39,42-44,46,47,50-52,55,60,65-68,134,135] and 43% to 72% 2 to 6 years post-operatively.[47,55,63,135-137] After LAGB, studies reported %EWL of 14% to 36% at 1 year, and 35% to 48% at 5 years' follow-up.[49,57,138-140] Studies comparing types of surgery reported that RYGB was associated with greater or equal weight loss compared with sleeve gastrectomy, and both RYGB and sleeve gastrectomy were associated with more weight loss than LAGB.[57,58,133,140-144] Most studies reported rates of resolution of type 2 diabetes, which ranged widely from 22% to 100%, apart from

the study by Moon and colleagues which reported remission of diabetes a mean of 24 months post-operatively in only 10% of patients after LAGB, 19% after RYGB, and 34% after SG.[133] Studies generally did not find a significant difference in diabetes resolution rates in the older compared with younger group,[39-42,46,48,52,54,55,59,63,145] although a higher rate of diabetes remission was reported in participants under the age of 40, compared with the ≥60 year old group in one study.[51] No studies reported outcomes of physical or cognitive function.

Safety

Of 38 studies comparing the safety of bariatric procedures in older vs younger groups, 16 found no difference in early mortality or complication rates between groups.[31,38,40,41,43,44,47,48,51,52,54,55,59,61,63,68] A further four studies found no difference between groups in overall complications, but higher rates of certain events in older participants, such as cardiac complications,[66] intubation for longer than 48 hours, acute kidney injury, sepsis and pulmonary embolus,[28] and bleeding.[39] In one study, in which a higher proportion of participants in the older group underwent LAGB, there was no difference in overall complications, but older participants had significantly lower 30-day readmission rates and higher new-onset gastro-oesophageal reflux compared to younger patients.[35] Dunkle-Blatter reported no significant differences after RYGB between older and younger participants in 30-day mortality or complications <30 days or >90 days, but a higher risk of major complications between 31 and 90 days in older compared with younger patients.[42] Higher risks of early mortality and/or complications (particularly early) were reported in older people in 15 studies.[29,30,33,34,37,46,50,53,58,60,64,65,67,146,147] One study[29] of Medicare beneficiaries who underwent bariatric surgery from 1997 to 2002 reported higher early mortality in those aged ≥65 years compared with younger patients (6.9 vs 2.3%), which was attributable in part to a higher proportion of older patients operated on by surgeons in the lowest quartile of bariatric surgery volume. Surgeons in the highest quartile of bariatric procedure volume had similar rates of early mortality across age groups (90-day mortality 1.8% in older vs 1.1% in patients <65 years; $P = 0.4$).[29] One study[49] found total complications and complications requiring re-operation were significantly more common in younger than older patients.

4 | DISCUSSION

The prevalence of obesity is particularly high in older adults.[148] The aim of this review is to examine current evidence for the efficacy and safety of lifestyle, pharmacological and surgical treatment for obesity in older adults. Our main findings are that there is a large pool of randomized, controlled studies demonstrating the benefits of weight loss with hypocaloric diets, including VLEDs, combined with exercise, in older people. Incorporation of multimodality exercise offsets loss of lean mass, and there are gains in physical function driven by exercise and fat loss. Where reported, adverse effects are generally mild and similar in nature to those seen in younger people. In contrast, there are no randomized studies examining outcomes of pharmacotherapy in elderly persons, and insufficient evidence of either benefit or harm to guide clinical decision-making regarding the use of pharmacotherapy in this age group. No randomized trials examining outcomes of bariatric surgery in elderly persons were identified, but nonetheless, a large number of older people have undergone bariatric surgery. Most of the available data are vulnerable to bias but indicate no significant differences in weight loss and resolution of type 2 diabetes in older compared with younger patients. Around half of studies reported comparable early mortality and overall complication rates in older and younger patients. Studies which compared types of surgery reported less weight loss and higher late complication rates for LAGB, consistent with findings in younger people.[149]

The effect of the increasing prevalence of obesity in the elderly on mortality is unclear; several epidemiological studies have described a phenomenon called the "obesity paradox," where obesity seems to be associated with a lower mortality in cardiovascular and other diseases. However, when adjustments for early death, cardiovascular fitness, and smoking status are made, the nadir of mortality occurs at a BMI within the normal range.[150] Large RCTs have shown no increase in mortality over 7 to 9 years in older persons with obesity randomized to lifestyle-based weight loss interventions,[123,124] and a retrospective examination of US Medicare-covered patients who underwent bariatric surgery between 2001 and 2004 found increased survival rates over 2 years when compared with a nonsurgical group with obesity, which started 11 months post-operatively in patients over the age of 65, compared with 6 months in patients aged less than 65 years.[56] Thus, the available evidence indicates that intentional weight loss in older people with obesity is not associated with increased mortality.

The limitations of this review include the paucity of data of any sort regarding pharmacotherapy in older persons, the lack of prospective, controlled studies for bariatric surgery, and the lack of long-term mortality data after any of these interventions. Even when older adults were studied, the majority of older participants were under the age of 70 years, which limits the generalizability of the findings to people over this age. This review did not evaluate the cost-effectiveness of treatment of obesity in the elderly, which is an important consideration for resource allocation. A recent cohort analysis in the United Kingdom by Gulliford and colleagues[151] examined this issue and found that the health care costs of bariatric surgery were exceeded by health benefits to people with obesity, with similar estimates in people aged 55 to 74 years compared with younger age groups.

4.1 | Future directions

The limitations of the current literature demonstrate the need for studies providing high-level evidence regarding the safety and efficacy of pharmacotherapy and bariatric surgery in older persons, and to delineate their place in the treatment of obesity in this age group. The higher prevalence of medical conditions, including diseases of ageing, and polypharmacy, mean that evaluations of benefits, risks, and costs in younger study participants cannot be assumed to be applicable to older persons. Future research should also investigate outcomes particularly relevant to the older age group, such as cognition, urinary incontinence, and falls risk.

4.2 | Conclusions

Lifestyle interventions for weight loss in older people should no longer be considered controversial, as they have clear benefits for obesity-related complications, and functional impairments. The available evidence suggests that bariatric surgery can be performed in older people with comparable weight loss and beneficial effects on obesity-related complications to younger people, and acceptable complication rates in carefully selected patients. There is a need for further studies examining the safety and efficacy of bariatric surgery, and obesity pharmacotherapy in older people, as well as outcomes of particular relevance to the older age group.

CONFLICTS OF INTEREST

Dr Cilla Haywood has received payment from iNova pharmaceuticals for development of educational presentations unrelated to this work. Dr Priya Sumithran has participated in advisory boards for Novo Nordisk unrelated to this work.

ORCID

Cilla Haywood https://orcid.org/0000-0002-8127-7014
Priya Sumithran https://orcid.org/0000-0002-9576-1050

REFERENCES

1. Peralta M, Ramos M, Lipert A, Martins J, Marques A. Prevalence and trends of overweight and obesity in older adults from 10 European countries from 2005 to 2013. *Scand J Public Health*. 2018;46:522-529.
2. Al Snih S, Ottenbacher KJ, Markides KS, Kuo YF, Eschbach K, Goodwin JS. The effect of obesity on disability vs mortality in older Americans. *Arch Intern Med*. 2007;167(8):774-780.
3. Barzilay JI, Blaum C, Moore T, et al. Insulin resistance and inflammation as precursors of frailty: the cardiovascular health study. *Arch Intern Med*. 2007;167(7):635-641.
4. Frisardi V, Solfrizzi V, Seripa D, et al. Metabolic-cognitive syndrome: a cross-talk between metabolic syndrome and Alzheimer's disease. *Ageing Res Rev*. 2010;9(4):399-417.
5. Cevenini E, Monti D, Franceschi C. Inflamm-ageing. *Curr Opin Clin Nutr Metab Care*. 2013;16(1):14-20.
6. Leenders M, Verdijk LB, van der Hoeven L, et al. Patients with type 2 diabetes show a greater decline in muscle mass, muscle strength, and functional capacity with aging. *J Am Med Dir Assoc*. 2013;14(8):585-592.
7. Heymsfield SB, Wadden TA. Mechanisms, pathophysiology, and management of obesity. *N Engl J Med*. 2017;376(3):254-266.
8. Sumithran P, Prendergast LA, Delbridge E, et al. Long-term persistence of hormonal adaptations to weight loss. *N Engl J Med*. 2011;365:1597-1604.
9. Fothergill E, Guo J, Howard L, et al. Persistent metabolic adaptation 6 years after "The Biggest Loser" competition. *Obesity (Silver Spring, Md)*. 2016;24:1612-1619.
10. Rosenbaum M, Sy M, Pavlovich K, Leibel RL, Hirsch J. Leptin reverses weight loss-induced changes in regional neural activity responses to visual food stimuli. *J Clin Invest*. 2008;118(7):2583-2591.
11. Yumuk V, Tsigos C, Fried M, et al. European guidelines for obesity management in adults. *Obes Facts*. 2015;8:402-424.
12. Jensen MD, Ryan DH, Apovian CM, et al. 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. *Circulation*. 2014;129(25 suppl 2):S102-S138.
13. Miller SL, Wolfe RR. The danger of weight loss in the elderly. *J Nutr Health Aging*. 2008;12:487-491.
14. Felix HC, West DS. Effectiveness of weight loss interventions for obese older adults. *Am J Health Promot*. 2013;27(3):191-199.
15. American Society for Metabolic and Bariatric Surgery. Estimate of bariatric surgery numbers, 2011–2017 (https://asmbs.org/resources/estimate-of-bariatric-surgery-numbers; accessed 12 October 2018).
16. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6:e1000097-e1000097.
17. Higgins JPT, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ (Clinical Research Ed)*. 2011;343. d5928-d28
18. Des Jarlais DC, Lyles C, Crepaz N. Improving the reporting quality of nonrandomized evaluations of behavioral and public health interventions: the TREND statement. *Am J Public Health*. 2004;94(3):361-366.
19. Beavers KM, Beavers DP, Nesbit BA, et al. Effect of an 18-month physical activity and weight loss intervention on body composition in overweight and obese older adults. *Obesity (Silver Spring, Md)*. 2014;22:325-331.
20. Messier SP, Loeser RF, Miller GD, et al. Exercise and dietary weight loss in overweight and obese older adults with knee osteoarthritis: the arthritis, diet, and activity promotion trial. *Arthritis Rheum*. 2004;50(5):1501-1510.
21. Messier SP, Mihalko SL, Legault C, et al. Effects of intensive diet and exercise on knee joint loads, inflammation, and clinical outcomes among overweight and obese adults with knee osteoarthritis: the IDEA randomized clinical trial. *Jama*. 2013;310(12):1263-1273.
22. Miller GD, Nicklas BJ, Davis C, Loeser RF, Lenchik L, Messier SP. Intensive weight loss program improves physical function in older obese adults with knee osteoarthritis. *Obesity (Silver Spring, Md)*. 2006;14:1219-1230.
23. Villareal DT, Chode S, Parimi N, et al. Weight loss, exercise, or both and physical function in obese older adults. *N Engl J Med*. 2011;364(13):1218-1229.
24. Christopher RJ, Morgan ME, Tang Y, Anderson C, Sanchez M, Shanahan W. Pharmacokinetics and tolerability of lorcaserin in special populations: elderly patients and patients with renal or hepatic impairment. *Clin Ther*. 2017;39:837-848. e7
25. Horie NC, Cercato C, Mancini MC, Halpern A. Long-term pharmacotherapy for obesity in elderly patients: a retrospective evaluation of medical records from a specialized obesity outpatient clinic. *Drugs Aging*. 2010;27(6):497-506.
26. Varli M, Turhan S, Aras S, Atli T, Erdogan G. Effects of weight loss on ventricular systolic and diastolic functions and left ventricular mass assessed by tissue Doppler imaging in obese geriatric women: preliminary report. *Aging Clin Exp Res*. 2010;22(3):206-211.
27. Perna S, Guido D, Bologna C, et al. Liraglutide and obesity in elderly: efficacy in fat loss and safety in order to prevent sarcopenia. A perspective case series study. *Aging Clin Exp Res*. 2016;28:1251-1257.
28. Dorman RB, Abraham AA, Al-Refaie WB, Parsons HM, Ikramuddin S, Habermann EB. Bariatric surgery outcomes in the elderly: an ACS NSQIP study. *J Gastrointest Surg*. 2012;16(1):35-44.
29. Flum DR, Salem L, Elrod JAB, Dellinger EP, Cheadle A, Chan L. Early mortality among Medicare beneficiaries undergoing bariatric surgical procedures. *Jama*. 2005;294(15):1903-1908.
30. Gebhart A, Young MT, Nguyen NT. Bariatric surgery in the elderly: 2009-2013. *Surg Obes Relat Dis*. 2015;11(2):393-398.
31. Hallowell PT, Stellato TA, Schuster M, Graf K, Robinson A, Jasper JJ. Avoidance of complications in older patients and Medicare recipients undergoing gastric bypass. *Arch Surg (Chicago, Ill: 1960)*. 2007;142:506-510.

32. Hazzan D, Chin EH, Steinhagen E, et al. Laparoscopic bariatric surgery can be safe for treatment of morbid obesity in patients older than 60 years. *Surg Obes Relat Dis*. 2006;2(6):613-616.
33. Livingston EH, Langert J. The impact of age and Medicare status on bariatric surgical outcomes. *Arch Surg (Chicago, Ill: 1960)*. 2006;141:1115-1120.
34. Qin C, Luo B, Aggarwal A, De Oliveira G, Kim JYS. Advanced age as an independent predictor of perioperative risk after laparoscopic sleeve gastrectomy (LSG). *Obes Surg*. 2015;25:406-412.
35. Quirante FP, Montorfano L, Rammohan R, et al. Is bariatric surgery safe in the elderly population? *Surg Endosc*. 2017;31:1538-1543.
36. Spaniolas K, Trus TL, Adrales GL, Quigley MT, Pories WJ, Laycock WS. Early morbidity and mortality of laparoscopic sleeve gastrectomy and gastric bypass in the elderly: a NSQIP analysis. *Surg Obes Relat Dis*. 2014;10(4):584-588.
37. Varela JE, Wilson SE, Nguyen NT. Outcomes of bariatric surgery in the elderly. *Am Surg*. 2006;72:865-869.
38. Abbas M, Cumella L, Zhang Y, et al. Outcomes of laparoscopic sleeve gastrectomy and roux-en-Y gastric bypass in patients older than 60. *Obes Surg*. 2015;25(12):2251-2256.
39. Bergeat D, Lechaux D, Ghaina A, Thibault R, Bouygues V. Postoperative outcomes of laparoscopic bariatric surgery in older obese patients: a matched case-control study. *Obes Surg*. 2017;27(6):1414-1422.
40. Burchett MA, McKenna DT, Selzer DJ, Choi JH, Mattar SG. Laparoscopic sleeve gastrectomy is safe and effective in elderly patients: a comparative analysis. *Obes Surg*. 2015;25(2):222-228.
41. Busetto L, Angrisani L, Basso N, Favretti F, Furbetta F, Lorenzo M. Safety and efficacy of laparoscopic adjustable gastric banding in the elderly. *Obesity (Silver Spring, Md)*. 2008;16:334-338.
42. Dunkle-Blatter SE, St Jean MR, Whitehead C, et al. Outcomes among elderly bariatric patients at a high-volume center. *Surg Obes Relat Dis*. 2007;3(2):163-169.
43. Gonzalez-Heredia R, Patel N, Sanchez-Johnsen L, et al. Does age influence bariatric surgery outcomes? *Bariatr Surg Pract P*. 2015;10:74-78.
44. Hayashi A, Maeda Y, Takemoto M, et al. Outcomes of laparoscopic sleeve gastrectomy in elderly obese Japanese patients. *Geriatr Gerontol Int*. 2017;17(11):2068-2073.
45. Heinberg LJ, Ashton K, Windover A, Merrell J. Older bariatric surgery candidates: is there greater psychological risk than for young and mid-life candidates? *Surg Obes Relat Dis*. 2012;8:616-622.
46. Leivonen MK, Juuti A, Jaser N, Mustonen H. Laparoscopic sleeve gastrectomy in patients over 59 years: early recovery and 12-month follow-up. *Obes Surg*. 2011;21(8):1180-1187.
47. Luppi CR-O, Balagué C, Targarona EM, et al. Laparoscopic sleeve gastrectomy in patients over 60 years: impact of age on weight loss and co-morbidity improvement. *Surg Obes Relat Dis*. 2015;11(2):296-301.
48. Michaud A, Marchand GB, Nadeau M, et al. Biliopancreatic diversion with duodenal switch in the elderly: long-term results of a matched-control study. *Obes Surg*. 2016;26(2):350-360.
49. Mittermair RP, Aigner F, Obermüller S. Results and complications after Swedish adjustable gastric banding in older patients. *Obes Surg*. 2008;18(12):1558-1562.
50. Mizrahi I, Alkurd A, Ghanem M, et al. Outcomes of laparoscopic sleeve gastrectomy in patients older than 60 years. *Obes Surg*. 2014;24(6):855-860.
51. Montastier E, Becouarn G, Bérard E, Guyonnet S, Topart P, Ritz P. Gastric bypass in older patients: complications, weight loss, and resolution of comorbidities at 2 years in a matched controlled study. *Obes Surg*. 2016;26(8):1806-1813.
52. Navarrete A, Corcelles R, Del Gobbo GD, Perez S, Vidal J, Lacy A. Sleeve gastrectomy in the elderly: a case-control study with long-term follow-up of 3 years. *Surg Obes Relat Dis*. 2017;13:575-580.
53. O'Rourke RW, Andrus J, Diggs BS, Scholz M, McConnell DB, Deveney CW. Perioperative morbidity associated with bariatric surgery: an academic center experience. *Arch Surg (Chicago, Ill: 1960)*. 2006;141:262-268.
54. Parmar C, Mahawar KK, Carr WRJ, Schroeder N, Balupuri S, Small PK. Bariatric surgery in septuagenarians: a comparison with <60 year olds. *Obes Surg*. 2017;27(12):3165-3169.
55. Pequignot A, Prevot F, Dhahri A, Rebibo L, Badaoui R, Regimbeau JM. Is sleeve gastrectomy still contraindicated for patients aged ≥60 years? A case-matched study with 24 months of follow-up. *Surg Obes Relat Dis*. 2015;11(5):1008-1013.
56. Perry CD, Hutter MM, Smith DB, Newhouse JP, McNeil BJ. Survival and changes in comorbidities after bariatric surgery. *Ann Surg*. 2008;247(1):21-27.
57. Quebbemann B, Engstrom D, Siegfried T, Garner K, Dallal R. Bariatric surgery in patients older than 65 years is safe and effective. *Surg Obes Relat Dis*. 2005;1(4):389-392.
58. Ritz P, Topart P, Benchetrit S, et al. Benefits and risks of bariatric surgery in patients aged more than 60 years. *Surg Obes Relat Dis*. 2014. https://doi.org/10.1016/j.soard.2013.12.012
59. Robert M, Pasquer A, Espalieu P, Laville M, Gouillat C, Disse E. Gastric bypass for obesity in the elderly: is it as appropriate as for young and middle-aged populations? *Obes Surg*. 2014;24:1662-1669.
60. Sosa JL, Pombo H, Pallavicini H, Ruiz-Rodriguez M. Laparoscopic gastric bypass beyond age 60. *Obes Surg*. 2004;14(10):1398-1401.
61. St Peter SD, Craft RO, Tiede JL, Swain JM. Impact of advanced age on weight loss and health benefits after laparoscopic gastric bypass. *Arch Surg (Chicago, Ill: 1960)*. 2005;140:165-168.
62. Sugerman HJ, DeMaria EJ, Kellum JM, Sugerman EL, Meador JG, Wolfe LG. Effects of bariatric surgery in older patients. *Ann Surg*. 2004;240(2):243-247.
63. Thereaux J, Poitou C, Barsamian C, Oppert J-M, Czernichow S, Bouillot J-L. Midterm outcomes of gastric bypass for elderly (aged ≥60 yr) patients: a comparative study. *Surg Obes Relat Dis*. 2015;11:836-841.
64. Van Nieuwenhove Y, Spriet E, Sablon T, et al. Metabolic surgery in patients over 60 years old: short- and long-term results. *Acta Chir Belg*. 2016;116:362-366.
65. van Rutte PWJ, Smulders JF, de Zoete JP, Nienhuijs SW. Outcome of sleeve gastrectomy as a primary bariatric procedure. *Br J Surg*. 2014;101(6):661-668.
66. Willkomm CM, Fisher TL, Barnes GS, Kennedy CI, Kuhn JA. Surgical weight loss >65 years old: is it worth the risk? *Surg Obes Relat Dis*. 2010;6:491-496.
67. Wool D, Bellatorre N, Wren S, Eisenberg D. Male patients above age 60 have as good outcomes as male patients 50-59 years old at 1-year follow-up after bariatric surgery. *Obes Surg*. 2009;19(1):18-21.
68. Yoon J, Sherman J, Argiroff A, et al. Laparoscopic sleeve gastrectomy and gastric bypass for the aging population. *Obes Surg*. 2016;26(11):2611-2615.
69. Ard JD, Cook M, Rushing J, et al. Impact on weight and physical function of intensive medical weight loss in older adults with stage II and III obesity. *Obesity (Silver Spring, Md)*. 2016;24:1861-1866.
70. Christensen P, Bliddal H, Riecke BF, Leeds AR, Astrup A, Christensen R. Comparison of a low-energy diet and a very low-energy diet in sedentary obese individuals: a pragmatic randomized controlled trial. *Clinical Obesity*. 2011;1(1):31-40.
71. Haywood CJ, Prendergast LA, Purcell K, et al. Very low calorie diets for weight loss in obese older adults-a randomized trial. *J Gerontol A Biol Sci Med Sci*. 2017;73:59-65.
72. Shea MK, Nicklas BJ, Marsh AP, et al. The effect of pioglitazone and resistance training on body composition in older men and women undergoing hypocaloric weight loss. *Obesity (Silver Spring, Md)*. 2011;19:1636-1646.

73. Porter Starr KN, Pieper CF, Orenduff MC, et al. Improved function with enhanced protein intake per meal: a pilot study of weight reduction in frail, obese older adults. *J Gerontol a Biol Sci Med Sci*. 2016;71(10):1369-1375.
74. Frimel TN, Sinacore DR, Villareal DT. Exercise attenuates the weight-loss-induced reduction in muscle mass in frail obese older adults. *Med Sci Sports Exerc*. 2008;40(7):1213-1219.
75. Nicklas BJ, Gaukstern JE, Beavers KM, Newman JC, Leng X, Rejeski WJ. Self-monitoring of spontaneous physical activity and sedentary behavior to prevent weight regain in older adults. *Obesity (Silver Spring, Md)*. 2014;22:1406-1412.
76. Anton SD, Manini TM, Milsom VA, et al. Effects of a weight loss plus exercise program on physical function in overweight, older women: a randomized controlled trial. *Clin Interv Aging*. 2011;6:141-149.
77. Nicklas BJ, Chmelo E, Delbono O, Carr JJ, Lyles MF, Marsh AP. Effects of resistance training with and without caloric restriction on physical function and mobility in overweight and obese older adults: a randomized controlled trial. *Am J Clin Nutr*. 2015;101:991-999.
78. Beavers DP, Beavers KM, Loeser RF, et al. The independent and combined effects of intensive weight loss and exercise training on bone mineral density in overweight and obese older adults with osteoarthritis. *Osteoarthritis and Cartilage/OARS, Osteoarthritis Research Society*. 2014;22(6):726-733.
79. Backx EMP, Tieland M, Borgonjen-van den Berg KJ, Claessen PR, van Loon LJC, de Groot LCPGM. Protein intake and lean body mass preservation during energy intake restriction in overweight older adults. *Int J Obes (2005)*. 2016;40:299-304.
80. Verreijen AM, Engberink MF, Memelink RG, van der Plas SE, Visser M, Weijs PJM. Effect of a high protein diet and/or resistance exercise on the preservation of fat free mass during weight loss in overweight and obese older adults: a randomized controlled trial. *Nutr J*. 2017;16(1):10-10.
81. Beavers KM, Gordon MM, Easter L, et al. Effect of protein source during weight loss on body composition, cardiometabolic risk and physical performance in abdominally obese, older adults: a pilot feeding study. *J Nutr Health Aging*. 2015;19(1):87-95.
82. Solomon TPJ, Haus JM, Cook MA, Flask CA, Kirwan JP. A low-glycemic diet lifestyle intervention improves fat utilization during exercise in older obese humans. *Obesity (Silver Spring, Md)*. 2013;21:2272-2278.
83. Espeland MA, Rejeski WJ, West DS, et al. Intensive weight loss intervention in older individuals: results from the action for health in diabetes type 2 diabetes mellitus trial. *J Am Geriatr Soc*. 2013;61(6):912-922.
84. Svetkey LP, Clark JM, Funk K, et al. Greater weight loss with increasing age in the weight loss maintenance trial. *Obesity (Silver Spring, Md)*. 2014;22:39-44.
85. Ades PA, Savage PD, Toth MJ, et al. High-calorie-expenditure exercise: a new approach to cardiac rehabilitation for overweight coronary patients. *Circulation*. 2009;119(20):2671-2678.
86. Waters DL, Vawter R, Qualls C, Chode S, Armamento-Villareal R, Villareal DT. Long-term maintenance of weight loss after lifestyle intervention in frail, obese older adults. *J Nutr Health Aging*. 2013;17(1):3-7.
87. Chmelo EA, Beavers DP, Lyles MF, Marsh AP, Nicklas BJ, Beavers KM. Legacy effects of short-term intentional weight loss on total body and thigh composition in overweight and obese older adults. *Nutr Diabetes*. 2016;6(4):e203-e203.
88. Akers JD, Cornett RA, Savla JS, Davy KP, Davy BM. Daily self-monitoring of body weight, step count, fruit/vegetable intake, and water consumption: a feasible and effective long-term weight loss maintenance approach. *J Acad Nutr Diet*. 2012;112:685-692. e2
89. Miller GD, Robinson SL. Impact of body composition on physical performance tasks in older obese women undergoing a moderate weight loss program. *J Frailty Aging*. 2013;2(1):27-32.
90. Wang X, Miller GD, Messier SP, Nicklas BJ. Knee strength maintained despite loss of lean body mass during weight loss in older obese adults with knee osteoarthritis. *J Gerontol a Biol Sci Med Sci*. 2007;62(8):866-871.
91. Santanasto AJ, Glynn NW, Newman MA, et al. Impact of weight loss on physical function with changes in strength, muscle mass, and muscle fat infiltration in overweight to moderately obese older adults: a randomized clinical trial. *Journal of Obesity*. 2011;2011:1-10.
92. Santanasto AJ, Newman AB, Strotmeyer ES, Boudreau RM, Goodpaster BH, Glynn NW. Effects of changes in regional body composition on physical function in older adults: a pilot randomized controlled trial. *J Nutr Health Aging*. 2015;19(9):913-921.
93. Armamento-Villareal R, Sadler C, Napoli N, et al. Weight loss in obese older adults increases serum sclerostin and impairs hip geometry but both are prevented by exercise training. *J Bone Miner Res*. 2012;27(5):1215-1221.
94. Shah K, Armamento-Villareal R, Parimi N, et al. Exercise training in obese older adults prevents increase in bone turnover and attenuates decrease in hip bone mineral density induced by weight loss despite decline in bone-active hormones. *J Bone Miner Res*. 2011;26(12):2851-2859.
95. Chao D, Espeland MA, Farmer D, et al. Effect of voluntary weight loss on bone mineral density in older overweight women. *J Am Geriatr Soc*. 2000;48(7):753-759.
96. Armamento-Villareal R, Aguirre LE, Qualls C, Villareal DT. Effect of lifestyle intervention on the hormonal profile of frail, obese older men. *J Nutr Health Aging*. 2016;20(3):334-340.
97. Miller GD, Nicklas BJ, Davis CC, Legault C, Messier SP. Basal growth hormone concentration increased following a weight loss focused dietary intervention in older overweight and obese women. *J Nutr Health Aging*. 2012;16(2):169-174.
98. Miller GD, Jenks MZ, Vendela M, Norris JL, Muday GK. Influence of weight loss, body composition, and lifestyle behaviors on plasma adipokines: a randomized weight loss trial in older men and women with symptomatic knee osteoarthritis. *Journal of Obesity*. 2012;2012:708505-708505.
99. O'Leary VB, Jorett AE, Marchetti CM, et al. Enhanced adiponectin multimer ratio and skeletal muscle adiponectin receptor expression following exercise training and diet in older insulin-resistant adults. *Am J Physiol Endocrinol Metab*. 2007;293:E421-E427.
100. Villareal DT, Banks M, Sinacore DR, Siener C, Klein S. Effect of weight loss and exercise on frailty in obese older adults. *Arch Intern Med*. 2006;166:860-866.
101. Focht BC, Rejeski WJ, Ambrosius WT, Katula JA, Messier SP. Exercise, self-efficacy, and mobility performance in overweight and obese older adults with knee osteoarthritis. *Arthritis Rheum*. 2005;53:659-665.
102. Messier SP, Loeser RF, Mitchell MN, et al. Exercise and weight loss in obese older adults with knee osteoarthritis: a preliminary study. *J Am Geriatr Soc*. 2000;48(9):1062-1072.
103. Rejeski WJ, Brubaker PH, Goff DC Jr, et al. Translating weight loss and physical activity programs into the community to preserve mobility in older, obese adults in poor cardiovascular health. *Arch Intern Med*. 2011;171(10):880-886.
104. Kotsis V, Jordan J, Micic D, et al. Obesity and cardiovascular risk: a call for action from the European Society of Hypertension Working Group of Obesity, Diabetes and the High-risk Patient and European Association for the Study of Obesity: part A: mechanisms of obesity induced hypertension, diabetes and dyslipidemia and practice guidelines for treatment. *J Hypertens*. 2018;36(7):1427-1440.
105. Villareal DT, Miller BV 3rd, Banks M, Fontana L, Sinacore DR, Klein S. Effect of lifestyle intervention on metabolic coronary heart disease risk factors in obese older adults. *Am J Clin Nutr*. 2006;84(6):1317-1323.

106. Dengo AL, Dennis EA, Orr JS, et al. Arterial destiffening with weight loss in overweight and obese middle-aged and older adults. *Hypertension (Dallas, Tex: 1979)*. 2010;55:855-861.
107. Katzel LI, Bleecker ER, Colman EG, Rogus EM, Sorkin JD, Goldberg AP. Effects of weight loss vs aerobic exercise training on risk factors for coronary disease in healthy, obese, middle-aged and older men. A randomized controlled trial. *Jama*. 1995;274(24):1915-1921.
108. Whelton PK, Appel LJ, Espeland MA, et al. Sodium reduction and weight loss in the treatment of hypertension in older persons: a randomized controlled trial of nonpharmacologic interventions in the elderly (TONE). *TONE Collaborative Research Group JAMA*. 1998;279:839-846.
109. Solomon TPJ, Haus JM, Marchetti CM, Stanley WC, Kirwan JP. Effects of exercise training and diet on lipid kinetics during free fatty acid-induced insulin resistance in older obese humans with impaired glucose tolerance. *Am J Physiol Endocrinol Metab*. 2009;297(2): E552-E559.
110. Villareal DT, Banks MR, Patterson BW, Polonsky KS, Klein S. Weight loss therapy improves pancreatic endocrine function in obese older adults. *Obesity (Silver Spring, Md)*. 2008;16:1349-1354.
111. Kitzman DW, Brubaker P, Morgan T, et al. Effect of caloric restriction or aerobic exercise training on peak oxygen consumption and quality of life in obese older patients with heart failure with preserved ejection fraction: a randomized clinical trial. *Jama*. 2016;315:36-46.
112. Beavers KM, Beavers DP, Newman JJ, et al. Effects of total and regional fat loss on plasma CRP and IL-6 in overweight and obese, older adults with knee osteoarthritis. *Osteoarthr Cartil*. 2015;23(2):249-256.
113. Beavers KM, Ambrosius WT, Nicklas BJ, Rejeski WJ. Independent and combined effects of physical activity and weight loss on inflammatory biomarkers in overweight and obese older adults. *J Am Geriatr Soc*. 2013;61(7):1089-1094.
114. Nicklas BJ, Ambrosius W, Messier SP, et al. Diet-induced weight loss, exercise, and chronic inflammation in older, obese adults: a randomized controlled clinical trial. *Am J Clin Nutr*. 2004;79(4):544-551.
115. Miller GD, Nicklas BJ, Loeser RF. Inflammatory biomarkers and physical function in older, obese adults with knee pain and self-reported osteoarthritis after intensive weight-loss therapy. *J Am Geriatr Soc*. 2008;56(4):644-651.
116. Miller GD. Improved nutrient intake in older obese adults undergoing a structured diet and exercise intentional weight loss program. *J Nutr Health Aging*. 2010;14:461-466.
117. Miller GD, Beavers DP, Hamm D, Mihalko SL, Messier SP. Nutrient intake during diet-induced weight loss and exercise interventions in a randomized trial in older overweight and obese adults. *J Nutr Health Aging*. 2017;21:1216-1224.
118. Napoli N, Shah K, Waters DL, Sinacore DR, Qualls C, Villareal DT. Effect of weight loss, exercise, or both on cognition and quality of life in obese older adults. *Am J Clin Nutr*. 2014;100(1):189-198.
119. Pope L, Harvey-Berino J, Savage P, et al. The impact of high-calorie-expenditure exercise on quality of life in older adults with coronary heart disease. *J Aging Phys Act*. 2011;19(2):99-116.
120. Rejeski WJ, Focht BC, Messier SP, Morgan T, Pahor M, Penninx B. Obese, older adults with knee osteoarthritis: weight loss, exercise, and quality of life. *Health Psychol*. 2002;21(5):419-426.
121. Horie NC, Serrao VT, Simon SS, et al. Cognitive effects of intentional weight loss in elderly obese individuals with mild cognitive impairment. *J Clin Endocrinol Metab*. 2016;101(3):1104-1112.
122. Ard JD, Gower B, Hunter G, et al. Effects of calorie restriction in obese older adults: the CROSSROADS randomized controlled trial. *J Gerontol a Biol Sci Med Sci*. 2017;73:73-80.
123. Shea MK, Houston DK, Nicklas BJ, et al. The effect of randomization to weight loss on total mortality in older overweight and obese adults: the ADAPT study. *J Gerontol a Biol Sci Med Sci*. 2010;65:519-525.
124. Shea MK, Nicklas BJ, Houston DK, et al. The effect of intentional weight loss on all-cause mortality in older adults: results of a randomized controlled weight-loss trial. *Am J Clin Nutr*. 2011;94(3):839-846.
125. Sevick MA, Miller GD, Loeser RF, Williamson JD, Messier SP. Cost-effectiveness of exercise and diet in overweight and obese adults with knee osteoarthritis. *Med Sci Sports Exerc*. 2009;41(6):1167-1174.
126. Batsis JA, Miranda WR, Prasad C, et al. Effect of bariatric surgery on cardiometabolic risk in elderly patients: a population-based study. *Geriatr Gerontol Int*. 2016;16(5):618-624.
127. Casillas RA, Kim B, Fischer H, Zelada Getty JL, Um SS, Coleman KJ. Comparative effectiveness of sleeve gastrectomy versus roux-en-Y gastric bypass for weight loss and safety outcomes in older adults. *Surg Obes Relat Dis*. 2017;13(9):1476-1483.
128. Garofalo F, Denis R, Pescarus R, Atlas H, Bacon SL, Garneau P. Long-term outcome after laparoscopic sleeve gastrectomy in patients over 65 years old: a retrospective analysis. *Surg Obes Relat Dis*. 2017;13(1):1-6.
129. Gray KD, Moore MD, Bellorin O, et al. Increased metabolic benefit for obese, elderly patients undergoing roux-en-Y gastric bypass vs sleeve gastrectomy. *Obes Surg*. 2018;28(3):636-642.
130. Ribeiro de Moraes M, Lúcia de Mendonça Soares B, Maio R, Pessoa de Araújo Burgos MG. Clinical-nutritional evolution of older women submitted to roux-en-Y gastric bypass. *Nutricion Hospitalaria*. 2014;31:1330-1335.
131. Trieu HT, Gonzalvo JP, Szomstein S, Rosenthal R. Safety and outcomes of laparoscopic gastric bypass surgery in patients 60 years of age and older. *Surg Obes Relat Dis*. 2007;3(3):383-386.
132. Clough A, Layani L, Shah A, Wheatley L, Taylor C. Laparoscopic gastric banding in over 60s. *Obes Surg*. 2011;21(1):10-17.
133. Moon RC, Kreimer F, Teixeira AF, Campos JM, Ferraz A, Jawad MA. Morbidity rates and weight loss after roux-en-Y gastric bypass, sleeve gastrectomy, and adjustable gastric banding in patients older than 60 years old: which procedure to choose? *Obes Surg*. 2016;26(4):730-736.
134. Nelson LG, Lopez PP, Haines K, et al. Outcomes of bariatric surgery in patients > or =65 years. *Surg Obes Relat Dis*. 2006;2(3):384-388.
135. Peraglie C. Laparoscopic mini-gastric bypass in patients age 60 and older. *Surg Endosc*. 2016;30(1):38-43.
136. Soto FC, Gari V, de la Garza JR, Szomstein S, Rosenthal RJ. Sleeve gastrectomy in the elderly: a safe and effective procedure with minimal morbidity and mortality. *Obes Surg*. 2013;23(9):1445-1449.
137. Vanommeslaeghe H, Deylgat B, Van Cauwenberge S, Dillemans B. Laparoscopic roux-en-Y gastric bypass in the elderly: feasibility, short-term safety, and impact on comorbidity and weight in 250 cases. *Surg Endosc*. 2015;29(4):910-915.
138. Loy JJ, Youn HA, Schwack B, Kurian MS, Fielding GA, Ren-Fielding CJ. Safety and efficacy of laparoscopic adjustable gastric banding in patients aged seventy and older. *Surg Obes Relat Dis*. 2014;10(2):284-289.
139. Musella M, Milone M, Maietta P, et al. Bariatric surgery in elderly patients. A comparison between gastric banding and sleeve gastrectomy with five years of follow up. *Int J Surg (London, England)*. 2014;12(Suppl 2):S69-S72.
140. Zaveri H, Surve A, Cottam D, et al. A comparison of outcomes of bariatric surgery in patient greater than 70 with 18 month of follow up. *Springerplus*. 2016;5(1):1740-1740.
141. Daigle CR, Andalib A, Corcelles R, Cetin D, Schauer PR, Brethauer SA. Bariatric and metabolic outcomes in the super-obese elderly. *Surg Obes Relat Dis*. 2016;12(1):132-137.
142. Nor Hanipah Z, Punchai S, Karas LA, et al. The outcome of bariatric surgery in patients aged 75 years and older. *Obes Surg*. 2017.
143. O'Keefe KL, Kemmeter PR, Kemmeter KD. Bariatric surgery outcomes in patients aged 65 years and older at an American Society for Metabolic and Bariatric Surgery Center of Excellence. *Obes Surg*. 2010;20(9):1199-1205.

144. Ramirez A, Roy M, Hidalgo JE, Szomstein S, Rosenthal RJ. Outcomes of bariatric surgery in patients >70 years old. *Surg Obes Relat Dis*. 2012;8(4):458-462.

145. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants. *Lancet (London, England)*. 2016;387:1513-1530.

146. Abu-Abeid S, Keidar A, Szold A. Resolution of chronic medical conditions after laparoscopic adjustable silicone gastric banding for the treatment of morbid obesity in the elderly. *Surg Endosc*. 2001;15(2):132-134.

147. Pajecki D, Santo MA, Joaquim HDG, *et al*. Bariatric surgery in the elderly: results of a mean follow-up of five years. *Arquivos Brasileiros De Cirurgia Digestiva: ABCD = Brazilian Archives Of Digestive Surgery*. 2015; 28 Suppl 1: 15–18.

148. Australian Bureau of Statistics. Australian health survey: first results, 2011–12 (Catalogue no. 4364.0.55.001), Commonwealth of Australia, 2012.

149. Chang S-H, Stoll CRT, Song J, Varela JE, Eagon CJ, Colditz GA. The effectiveness and risks of bariatric surgery: an updated systematic review and meta-analysis, 2003-2012. *JAMA Surg*. 2014;149(3):275-287.

150. Fontana L, Hu FB. Optimal body weight for health and longevity: bridging basic, clinical, and population research. *Aging Cell*. 2014;13(3):391-400.

151. Gulliford MC, Charlton J, Prevost T, et al. Costs and outcomes of increasing access to bariatric surgery: cohort study and cost-effectiveness analysis using electronic health records. *Value Health*. 2017;20(1):85-92.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Haywood C, Sumithran P. Treatment of obesity in older persons—A systematic review. *Obesity Reviews*. 2019;20:588–598. https://doi.org/10.1111/obr.12815