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Review

Body composition changes after weight-loss interventions for overweight and obesity

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SUMMARY

Background & aims: Weight-loss interventions to correct overweight and obesity are very popular but often inappropriate and unsuccessful.
Methods: In this review we evaluated studies on body composition changes during and after different medical and surgical interventions aimed at achieving stable weight loss in overweight and obese individuals.
Results: Most of the available literature and good clinical practice observations deal mainly with post-menopausal overweight and obese women, and, to a lesser extent adolescents and elderly, female and male, populations. These studies suggest that weight-loss maintenance interventions should have greater consideration and priority than simple weight-loss treatments. At a long term follow up (over one year), relatively high protein, moderately low calorie, low glycemic index diets, associated with a daily, moderate intensity, physical exercise (of at least 30 min), appear to be more successful in limiting long term relapse, maintaining fat free mass and achieving the highest fat loss. Diet alone or physical exercise alone does not produce similar results. Health professional training and practice also appear a challenging target.
Conclusions: Adequate dietetic advice plus regular physical exercise avoid the fat-free-mass loss usually observed in the relapse of the weight cycling syndrome and prevent the onset of sarcopenic obesity.
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1. Introduction

The uncontrolled overweight and obesity epidemic is continuously emphasized by national and international health care reports as well as by popular newsmagazines; its worldwide diffusion represents one of the main current health hazards.[1] Prevention and treatment still appear very far from being even partially achieved, due to the poor efficacy of preventive interventions and pharmacological treatments.[2] Due to their diffusion, another drawback is represented by the side effects of inadequate "popular" interventions for weight loss, usually leading to the weight cycling syndrome and significantly impairing body composition. Finally national health care systems do not usually give adequate attention to obesity management and to the training of health professionals to prevent and treat obesity.[3,4]

The aim of this review is focused on body composition changes as related to current clinical practice, during and after intentional weight loss in overweight and obesity, trying to address several questions as summarized in Table 1. In particular: are there differences in body composition after weight loss due to medical approaches? What is therefore the preferred medical intervention to improve weight-loss maintenance? Does physical exercise (PE) have an additive effect on weight loss, and which type of PE should be prescribed? Are there predictive factors for weight loss directly or indirectly linked to body composition? Does the composition of a low calorie diet affect body composition during and after weight loss? Do low calorie/high protein diets contribute to a better body composition and to maintain weight loss? Does the weight cycling syndrome affect body composition; if so how can its occurrence be reduced? Are there differences in the characteristics of body composition following acute weight loss immediately after bariatric surgery, or after stable weight loss obtained with medical interventions? Finally, is intentional weight-loss deleterious?

1.1. Medium and long term weight loss and the type of medical intervention

A systematic review of this topic has been recently published by Franz et al.[5] The authors consider 80 clinical trials with at least one

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Table 1
Body composition changes during weight loss in overweight and obesity: a synopsis.

Question	Evidence	Reference no.
Long term WL and type of medical intervention	The combination of a reasonably low energy diet and regular aerobic PE helps to obtain long term positive results on weight loss.	5,6,11
	WL is higher after pharmacological treatments	7
Effectiveness of hypocaloric diet plus physical exercise	Diet with a daily 500 kcal restriction, plus 30 min of moderate intensity PE, five times a week, is appropriate.	10,12–14,17
Weight loss and body composition	PE plus diet enhances FFM maintenance versus diet only.	16
Predictive factors of weight loss	Higher baseline serum leptin is associated with limited weight and % fat loss.	18
Diet composition (Prot/CHO ratio)	High protein intake is associated with FFM sparing and moderately greater body fat loss.	20–24,26
	A balanced intake of proteins at each meal positively affects protein synthesis.	27
	Similar WL regardless of the Prot/CHO ratio of the diet.	25
Effect of weight cycling on body composition	More FFM lost during WL as compared with that gained during relapse periods	34,35
Composition of maintenance diet	Addition of 30 g proteins/day limits weight regain after WL	36
Bariatric (LGB) versus medical treatment	Greater FFM loss compared with a conventional low calorie diet plus PE	42
Body composition changes after bariatric surgery	L-RYGB versus LVBG appears to be effective in achieving more fat and less FFM loss.	37,39
Is intentional weight loss deleterious?	Stable body weight loss has no adverse effects on body composition and protein metabolism.	43

WL = weight loss; FFM = fat-free-mass loss; laparoscopic Roux-en Y-gastric bypass (L-RYGB); laparoscopic vertical banded gastroplasty (LVBG); laparoscopic gastric banding (LGB).

year follow up, dealing with different types of weight-loss interventions: diet alone, physical exercise alone, meal replacement, very low energy diets, diet plus physical exercise, weight-loss medications, simple dietetic advice. The main conclusions of the review are that weight loss tends to reach a plateau, ranging between 5.0 and 8.5 kg (5–9% initial body weight) after six months' treatment, gradually decreasing to 3.0–5.0 kg (3–6% initial body weight) after 48 months. Less effective types of intervention are dietetic advice alone and physical exercise alone. The final suggestions by the authors are that more attention should be focused on continued weight-loss management and maintenance, and that the prescription of a reasonably low energy diet (about 1200 kcal/day in women and 1500 kcal/day in men) plus regular aerobic physical exercise may help to obtain long term positive results. In conclusion, the combination of diet and physical exercise intervention is successful but not when considered separately. Similar results have been obtained by Curioni and Lourenco who compared, after a 1 year follow up, a weight-loss (WL) intervention based on diet and physical exercise (PE) versus diet alone, observing a WL of 6.7 versus only 4.5 kg respectively.[6] Dovketis et al. compared diet plus lifestyle intervention lasting 2–4 years versus pharmacological treatments, taken for 1–2 years: in the first case WL was of about 5 kg and in the second it ranged between 5 and 10 kg.[7] Finally, a recent review by Kirk et al. highlights the value of multi-disciplinary interventions to obtain an effective weight management, when proposed for a sufficiently long period of time and worked in cooperation with health care professionals.[8]

1.2. Additional effects of physical exercise on weight loss

Physical activity can be defined as any voluntary body movement generated by the contraction of skeletal muscles resulting in energy expenditure. The crucial role of a physically active lifestyle for maintaining and improving physical, physiological and psychological health is well recognized. Several reports document beneficial effects of aerobic physical exercise on type 2 diabetes, cardiovascular diseases (in particular arterial hypertension), osteoporosis etc.[9] Aerobic exercise in fact exerts a positive influence, among others, on aerobic capacity, mitochondrial enzyme activities, insulin sensitivity, thus suggesting a potential common pathway with the beneficial effects of calorie restriction.[10] For these reasons, aerobic physical exercise should also promote higher body fat loss and WL maintenance in overweight and obese individuals.

Franz et al. and Fogelholm and Kukkonen-Harjula addressed this topic in two meta-analysis, reaching similar conclusions.[5,11] Franz et al. found an extra WL of about 1.3 kg achieved with PE associated with diet in a 24-month follow up, whilst in the other study, the additional effect of PE was slightly higher, about 1.8 kg after 20 months of observation. As expected and remarked by Franz et al., PE has further positive effects, in terms of improved blood lipid, insulin sensitivity and all-cause mortality.

1.3. Which type of diet and physical exercise are usually prescribed in good clinical practice, and why?

Good clinical practice suggests to prescribe a diet with a daily intake of approximately 500 kcal less than the estimated habitual intake, at least in overweight and type 1 and 2 obesity. Concerning PE, it is recommended to provide effective and personalized lifestyle interventions.[10,13] A general advice is to carry out 30 min of moderate intensity PE five times a week, gradually increasing up to 60 min per session, if appropriate.[13,14] As reported by Nicklas et al., a moderate intensity PE should induce an extra weekly energy expenditure of about 700 kcal/week, corresponding to 8 kcal kg/body weight/week: these indications appear in accordance with public health exercise recommendations for post-menopausal women.[12,15] Nicklas et al. have also elegantly shown, by dual-energy X-ray absorptiometry (DXA) measurements and in obese post-menopausal women, that moderate intensity PE (plus diet) is as effective as vigorous intensity PE to obtain significant extra fat loss – associated with lower fat-free-mass (FFM) loss – when compared to diet alone. In particular overall WL was similar, but body composition changes were much better after 6 weeks of diet plus PE, compared to diet alone. Direct or indirect evidence of the beneficial effects of PE on FFM have also been described in other studies; Ballor et al., using hydrostatic weighing to measure body composition, showed in an 8 weeks study, in 40 obese individuals, that exercise training plus diet enhanced (of about 0.43 kg) FFM maintenance versus diet only, with a reported FFM loss of about −0.91 kg.[16] Similar results have been described by Kerksick et al., who, using DXA, showed that PE plus diet improved WL, visceral fat loss, aerobic capacity and maximal strength which, taken together, are functional signs of improved FFM.[17] In the same study energy expenditure was not depressed as when only diet was prescribed.

1.4. Are there predictive factors of weight loss directly linked to body composition?

Several possible predictive factors of WL have been described although their analysis is outside the scope of the present manuscript. In this review we simply focus on serum leptin, which is produced by adipose tissue to an extent directly proportional to fat

depots. For this reason leptin may represent the best indicator of body composition characteristics, and changes, in overweight and obese individuals. Leptin, as well known, contributes to the regulation of food intake, energy expenditure and body fat by a direct CNS action; it has a twofold regulatory role: when body weight is stable, it signals body fat stores; on the other hand, during weight loss, it contributes to energy balance regulation by increasing appetite and decreasing energy expenditure. Essential obesity, the most common type of obesity, is characterized by leptin resistance. From these preliminary considerations it appears quite reasonable to suppose that serum leptin may also represent a predictive factor of weight loss during WL interventions. Murer et al. conducted a study on 203 children and adolescents participating in a 2 months inpatient weight-loss intervention, consisting in diet plus physical exercise and behavior intervention: they were able to confirm that higher baseline serum leptin (i.e. leptin resistance level) is associated with less weight loss.[18] After the two months' intervention, total weight loss was about 13.9 kg and fat loss about 9.2 kg, with a 76% decrease in serum leptin levels. Baseline leptin represented also a negative predictor for % fat loss not only after the two months inpatient treatment, but also in the medium (6 mo) and long term (12 mo) follow up. Furthermore, serum leptin changes during the first two months of treatment were positively related with % fat loss at 2 and 6 months follow up: both findings might well be indirect indexes of the role of leptin resistance on body fat loss due to medical intervention also in medium–long term follow up.

1.5. Diet composition and weight loss

Another important and debated issue of clinical interventions aimed at weight loss is the composition of the diet. Specialized literature has mostly explored the macronutrient distribution and in particular the protein-carbohydrate ratio (Prot/CHO). The most debated topic is the claim of faster and larger WL, at least in the short term, of low CHO – low calorie diets. Actually low CHO diets tend to provide more proteins than 0.8 g/kg body weight per day, as recommended by RDA.[19] RDA recommendations refer to normal-weight subjects in steady-state energy balance. Energy restriction, even in obesity, is expected to increase protein requirements: consequently low calorie diets should require more proteins than RDA. The effect of high Prot/CHO diets on weight loss and FFM maintenance has been extensively evaluated in a meta-analysis by Krieger et al. who examined 165 treatments from 87 studies based on dietary interventions with diets based on >1000 kcal per day prescribed for more than 4 weeks.[20] This meta-analysis evaluated in particular the effect of the Prot/CHO and high protein intake on total weight loss and body composition changes induced by high calorie diets, showing that an extra weight loss of 1.6–1.7 kg was obtained when CHO intake was in the lowest quartile (CHO < 35% of total energy intake) versus the highest. When studies lasting more than 12 weeks were considered, extra weight loss with low CHO diets was of about 6.6 kg. Krieger et al. also underline that in four-week intervention studies, in which protein intake was higher than 1.05 g/kg/body weight per day, there was an FFM retention of about 0.96 kg, whereas in those lasting 12 weeks FFM retention was 1.21 kg. High protein intake was also associated with a moderately greater body fat loss (1.32%) than with a protein intake less than 0.7 g/kg body weight per day (0.64%). Other studies have shown the short term (8–12 wks) effects of high protein diets on weight loss in post-menopausal women, but these findings are not confirmed in men. Farnsworth et al.[21] reported their observations on post-menopausal women who underwent a 12 wks high protein diet with 110 g/day high biological value proteins; at the DXA measurements, they found a better preservation of FFM, but no additional effects on weight and fat loss. Layman et al.,[22] again in obese post-menopausal women, showed by DXA measurements, a better FFM preservation with increased fat loss after 10 wks high protein diets with 125 g proteins per day; Parker et al.[23] obtained similar results in type 2 diabetic obese women. These short term observations have been confirmed in a medium – long term follow up (6 months) by Skov et al.[24] who observed, by DXA, more fat loss (7.6 versus 4.3 kg) and intra-abdominal adipose tissue decrease (33 versus 17 cm^2) in waist and hip circumferences, with high protein versus normoproteic high calorie diets. In conclusion several studies are in support of high protein/high calorie diets (i.e. a high Prot/CHO, mostly due to an increase in protein intake) in particular for the treatment of obese post-menopausal women. Several hypothesis may be formulated to explain the higher weight loss obtained with low CHO/high protein diets: reduced energy intake (due to increased satiety) and a greater thermogenic effect of protein (gluconeogenesis from amino acids) than carbohydrates (CHO); high protein diets, differently from high CHO diets, reduce insulin secretion and increase FFA mobilization. An increased chetogenesis is expected even when carbohydrate intake is below 100 g/day. Other suggested mechanism contributing to the fastest and higher weight loss with low CHO/high protein diets involve increased body water excretion. Two recent large clinical nutritional studies have addressed the topic of weight loss and macronutrient composition of the low calorie diets. Sacks et al.[25] treated a US group of 811 obese individuals with four different low calorie diets with a daily calorie restriction of 750 calorie from baseline. After a six months' intervention and a 2 years' follow up, weight loss was similar regardless of the macronutrient composition of the four experimental diets. Meinert-Larsen et al.[26] studied a large European group of obese individuals (773 participants) with a dietary protocol focusing more on weight maintenance than on weight loss. Indeed, after 8 weeks of 800 kcal diet, patients were assigned for a 26 week period to four low fat maintenance diets with different protein content, glycemic index and load. This study concluded that a modest increase in protein content and a mild reduction in the glycemic load (or index) of the diet led to improved study compliance and better maintenance of the weight loss.

We may reasonably conclude that high protein, low calorie, low glycemic index diets may be beneficial in weight-loss interventions. Then the question arises on the best way to supplement proteins during low calorie diets. A recent study by Paddon-Jones and Rasmussen[27] suggests that a balanced assumption of proteins (25–30 g) at each meal – breakfast, lunch and dinner – affects protein synthesis much better than giving the whole protein supplement during the evening meal, thus suggesting that protein distribution at meals has a nutritional role.

Limited data, however are available on the potential impact of high protein intake on bone mineral density in obese individuals when assuming a low calorie high protein diet. In normal-weight individuals normocaloric high/protein diet does not seem to affect bone density. High protein diets increase calcium gut absorption, improve lean body mass and increase insulin-like growth factor 1 secretion which, taken together, balance the negative effects of dietary acid load and increased urinary calcium excretion due to the high protein intake. Therefore a general suggestion in normal-weight individuals taking a high protein diet is to enrich the diet with a high intake of fruits and vegetables with alkalizing function.[28]

Conflicting data are available in obese individuals when submitted to low calorie/high protein diets showing an increased bone turnover and decreased mineral density in some studies[29,30] and a decreased mineral bone loss in other studies,[31,32] in particular when giving dairy proteins.[30] Bray et al. have recently reconsidered the role of the fat/carbohydrate ratio of the low calorie diet on fat-free-mass changes, evaluated by deuterium and oxygen –18

distribution spaces, in a six months follow-up study. Authors have shown that patients eating the low calorie, high fat diet lost significantly more fat free mass than the low fat group, but the last group had also significantly higher increased physical exercise than the other group.[33] In conclusion this recent study confirms a positive influence of low fat relatively high carbohydrate/high calorie diet on body composition, not excluding the concomitant influence of a more regular physical exercise.

1.6. Effect of weight cycling on body composition

A quite common finding in clinical practice is the pendulum of "dieters" between weight loss and weight increase: the well known "weight cycling syndrome". This is a real "iatrogenic" complication of obesity particularly when body composition changes are not adequately considered. Beavers et al. have recently shown, in post-menopausal obese women on dietary treatment for 6 months who regained weight one year later, that for each 1 kg fat loss during the weight-loss intervention, 0.26 kg of fat free mass was also lost, as shown by DXA. Vice versa, for every kg of fat regained over the following 12 months, only 0.12 kg of fat free mass was regained, concluding that in weight cycling post-menopausal women fat mass is regained to a larger extent than fat free mass, thus facilitating the development of sarcopenic obesity.[34] These findings confirm previous observations in older (70–79 years) men and women showing that in a 2 year follow up with weight fluctuations +/−3%, more fat free mass is lost during the weight loss than what is gained during the weight regain period, again favoring the development of sarcopenic obesity.[35] Beneficial effects of protein supplements have also been explored to verify the possible action of extra protein intake on weight cycling prevention and long term weight maintenance. Lejeune et al. have shown that addition of 30 g proteins/day should limit weight regain after weight loss. These authors, in a study carried out in more than 100 individuals who, after an initial 4 week period of very low energy diet, were on a maintenance diet enriched with an extra 30 g proteins for 6 months, showed lower weight regain, decreased waist circumference, smaller increase in respiratory quotient compared with the control group.[36] Unfortunately, at least to our knowledge, no data are available on weight maintenance efficacy when returning to balanced (normoproteic) diets after high protein, hypocaloric diets. We can only speculate that FFM can be preserved, following WL, with a balanced, relatively hyperproteic diet.

1.7. Body composition changes after bariatric surgery

Fat-free-mass (FFM) loss represents a significant component of weight loss after bariatric surgery, in particular during the first six months after surgery. Laparoscopic Roux-en Y-gastric bypass appears to be effective in obtaining more fat and less FFM loss when compared with laparoscopic vertical banded gastroplasty (LVBG).[37] Nevertheless, Chaston et al.,[38] in a systematic review of the literature, report that fat-free-mass loss represents 31.3% of the weight loss due to Roux-en-Y gastric bypass (RYGB). However absolute FFM loss decreases in the second six months after surgery.[39] From these considerations, to preserve fat free body mass, a careful dietary follow-up prescribing high protein diets[40] associated with a regular physical exercise,[41] is recommended after bariatric surgery.

Our group has evaluated the body composition changes in severely obese patients, according to the type of approach, i.e., medical versus bariatric treatment. With a 10% weight loss obtained in 6 weeks, 20 obese patients submitted to laparoscopic gastric banding showed a significantly greater fat-free-mass loss evaluated with Bioimpedenziometry (BIA) as compared to age, body mass index (BMI = kg/m^2) and sex matched obese individuals treated with a conventional low calorie diet plus physical exercise for 30 weeks.[42] Actually, the study compared body composition changes after acute weight loss obtained surgically versus chronic weight loss obtained with standardized medical treatment. However it is clear that in the immediate post-operative phase of weight loss (but also all over the post-surgical follow up) specific attention should be given to the composition of the diet prescribed to these obese patients.

1.8. Is weight loss for obese and overweight individuals deleterious?

This appears to be the last but most intriguing question. If we consider the frequency of relapse in medically treated "dieters" much more attention should be given to weight maintenance protocols than to mere weight loss. In this context weight-loss predictors appear of some relevance. In well motivated individuals a low calorie, relatively high protein diet plus regular, moderate intensity, aerobic physical exercise favors long term weight loss and limits the negative effects of weight regain. Gallagher et al., in an elegant and comprehensive study measured in a small group of 14 obese post-menopausal women, followed for 16 weeks with a 1200 kcal diet, fat free mass and appendicular lean soft tissue by DXA, body cell mass (BCM) by K40 whole body counting, total body water (TBW) by tritium dilution, skeletal muscle (SM) by whole body magnetic resonance imaging (MRI) and protein turnover by 13-leucine kinetics. Relative to a weight loss of 9.6 kg (10.7% initial body weight) reductions of SM, TBW, BCM, appendicular lean soft tissue were consistent with total decrease in body weight, thus concluding that stable body weight loss in obese post-menopausal women has no adverse effects on body composition and protein metabolism.[43]

2. Conclusion

Most of the current recommendation essentially look at obesity as a homogeneous condition that is amenable to treatment either simply by caloric reduction and/or increasing physical activity. However, subjects seeking weight-loss support often present with a range of other issues that may hinder their ability to lose weight, including behavioral and mental health issues, arthritis derived chronic pain and family or social barriers. Available data usually do not distinguish between different causes of obesity or even stages of obesity with related complications. Nonetheless, the importance of identifying and thereby addressing all these aspects is critical to understand the complexity of the disease in order to improve obesity management.

Therefore, body composition changes during intentional weight loss in overweight and obese individuals deserve specific clinical attention and care. Individualized weight reduction programs should focus on long term weight-loss maintenance more than short term simple weight loss. In this context, regular and moderate intensity physical exercise plus a low calorie, relatively high protein diet may enhance, in particular in post-menopausal women, fat-free-mass maintenance. Uncontrolled weight cycling (continuous diet relapse with increased body weight) that significantly impairs body composition, with a more marked imbalance between fat free mass and fat mass, should be considered deleterious for the patient and carefully prevented and avoided by the expert clinician.

Statement of authorship

Each author participated sufficiently, intellectually and practically, in the work to take public responsibility for the content of the article.

LS drafted the manuscript, FC conceived of the study, and participated in its design and coordination and helped to draft the manuscript. FP made the final revision of the study.

All authors read and approved the final manuscript.

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