Conference on ‘Sustainable diet and food security’

Long-term weight status in regainers after weight loss by lifestyle intervention: status and challenges

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After having participated in a weight loss trial, most participants do not stabilise the obtained weight loss but return to their initial weight. The aim of this review is to describe the main determinants of continued low weight status after weight loss, and the effectiveness of physical activity (PA), energy restriction and macronutrient composition of the diet for low long-term weight regain. Studies with intervention periods of at least 3 months duration of weight reduction measures and a follow-up at least 2 years after the intervention period were considered as eligible for the review. Owing to limited data, the studies describing the role of PA in weight management were eligible with a follow-up of 1 year only. It appears that a diet with self-regulation of dietary intake seems to be given a prominent role in the strategy of successful long-term weight loss among the obese. This measure could be combined with behaviour therapy and PA and tailored to the individual situation. However, considering available evidence it is difficult to conclude regarding unambiguous measures and to recommend a specific dietary intervention. Nevertheless, interventions should be effective in promoting intrinsic motivation and self-efficacy. The harmonisation and standardisation of data collection in the follow-up period of long-term weight loss studies is a major challenge.

Weight regain: Weight status: Obesity

According to the World Health Organization, 12% of adults aged over 20 years are obese globally (2008) as well as in the World Health Organization European Region with 58.3% of males and 51.2% of females being overweight (1). Therefore successful approaches for the treatment of obesity are being looked for since even a moderate reduction of weight of about 10% can significantly decrease the severity of obesity-associated risk factors (2). It has already been shown that obese subjects can manage to achieve the expected weight loss, with special emphasis being put on proper diet and physical activity (PA). Unfortunately, most subjects participating in such short-term weight loss studies (~70%) will regain at least half the weight lost within the next 2 years and will return to their baseline weight within the next 3–5 years (3–5).

The challenge for clinicians and nutritionists is to develop weight management strategies for obese people which not only promote initial weight loss, but also contribute to a subsequent weight maintenance phase (6–9). From a nutritional perspective, weight management strategies should take into account personalised dietary programmes.

In this review, we analysed the intervention studies with long-term weight reduction incorporating dietary and PA means in overweight and obese subjects. The studies with at least 3 months intervention and a follow-up period of at least 2 years were considered as
eligible for the analysis. Due to limited data, the studies describing the role of PA in weight management were eligible with a follow-up of 1 year only.

The aim of this review is to describe the main determinants of continued low weight status after weight loss, and the effectiveness of energy restriction and macronutrient composition of the diet and of PA on low long-term weight regain.

### Potential determinants of continued low weight status after weight loss

It is known that important changes in eating behaviours can differ between short- and long-term weight changes\(^\text{(10)}\). Reyes et al.\(^\text{(11)}\) documented the existing similarities and differences between weight loss in regainers (those who had regained ≥33 % of their weight loss as compared with the end of intervention) and subsequent maintainers (those who had sustained their initial weight loss for at least 1 year and regained ≤15 % as compared with the end of intervention; Table 1). They identified only three determinants of low weight status after using a slimming diet: self-monitoring of dietary intake over time, large support during the weight regain phase, and using small size clothing. Furthermore, they reported the main determinants connected with unsuccessful maintenance of low weight status: worse adaptation to changes in the lifestyle to continue diet and PA, using less positive self-talk and loss of effectiveness in problem-solving techniques during the weight regain phase. Researchers\(^\text{(3)}\) have speculated on some additional explanations why obese subjects gain weight after successful weight loss. The main factors according to Byrne et al.\(^\text{(3)}\) were: failure to achieve weight goals and dissatisfaction with the weight achieved, a tendency to evaluate self-worthiness in terms of weight and shape, lack of vigilance in weight control and a dichotomous (black-and-white) thinking style. Regainers also did not permit themselves to any of the food they really enjoyed and therefore felt deprived\(^\text{(12)}\).

Moreover, stress during the weight regain phase seems to be an important factor for weight change, also demonstrating it to be a critical factor for inducing overeating\(^\text{(13)}\). The study of Sarlio-Lähteenkorva et al.\(^\text{(14)}\) carried out in men with 6 and 15 years follow-up documented the failure to maintain weight loss as a result of a stressful life and high alcohol intake.

One of the most important aspects influencing the motivation towards a long-term weight regain is also the low initial weight loss\(^\text{(15)}\). The retrospective analyses of pooled data from two multicentric, randomised, placebo-controlled clinical trials were in line with this statement. Weight loss of ≥5 % body weight after 12 weeks diet and Orlistat were a good indicator of 2-year weight loss, whereas ≥2.5 kg initial weight loss during the 4-week run-in phase and ≥10 % weight loss after 6 months did not add significantly to the prediction of the 2-year outcome\(^\text{(16)}\). In weight regainers, it has also been shown that self-monitoring of food intake and weight control decline over time\(^\text{(3)}\). According to Teixeira et al.\(^\text{(17)}\) lowering emotional eating and adopting a flexible dietary restraint pattern are critical factors for sustained low weight status. Therefore, for long-term success, interventions must also be effective in promoting exercise, intrinsic motivation and self-efficacy. Self-efficacy can be improved during the study conduct; however, in regainers it was connected with low intrinsic motivation leading to easily giving up\(^\text{(18)}\). In the study by Dennis and Golberg\(^\text{(19)}\) the type of disbelievers berating themselves for their perceived aberrant behaviour intensified their already hesitant self-efficacy beliefs. The disbelieving women did not believe they had the inner strength or self-control to do what was needed to be done to maintain their weight successfully. Additionally, they reflected doubt, self-recrimination, and marked dependency needs in weight control.

Some studies could show that weight regain is more pronounced when food choice is unrestricted and high in fat content\(^\text{(20,21)}\). However, a high fat content of the diet might prevent food craving which has been also identified as factor favouring weight regain\(^\text{(22)}\).

### Table 1. The potential determinants of weight status after using slimming diet in obese subjects\(^\text{(11)}\)

<table>
<thead>
<tr>
<th>Potential determinants of weight status</th>
<th>Maintainers v. Regainers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using tailored clothing as the primary indicator for weight status</td>
<td>X</td>
</tr>
<tr>
<td>Greater support during weight loss maintenance</td>
<td>X</td>
</tr>
<tr>
<td>Self-monitoring of intake over time</td>
<td>X</td>
</tr>
<tr>
<td>More difficulties continuing food and/or activity routines over time ‘by regainers’</td>
<td></td>
</tr>
<tr>
<td>Avoided the scale out of shame or denial, weighing themselves less often because they knew it was</td>
<td>X</td>
</tr>
<tr>
<td>undesirable news ‘by regainers’</td>
<td></td>
</tr>
<tr>
<td>Applying more unproductive problem-solving styles around the challenges of maintenance, citing</td>
<td>X</td>
</tr>
<tr>
<td>avoidance or denial related to weight regain ‘by regainers’</td>
<td></td>
</tr>
<tr>
<td>Less adapting to changes and adjusting their lifestyle in order to continue diet and exercise habits</td>
<td>X</td>
</tr>
<tr>
<td>‘by regainers’</td>
<td></td>
</tr>
<tr>
<td>Using less positive self-talk during weight loss maintenance ‘by regainers’</td>
<td>X</td>
</tr>
<tr>
<td>Offering less detail about the reaction to setbacks and more likely to put off immediate changes</td>
<td>X</td>
</tr>
<tr>
<td>‘by regainers’</td>
<td></td>
</tr>
<tr>
<td>Having a seemingly lower self-efficacy concerning weight regain, and cited less specific tactics to use immediately ‘by regainers’</td>
<td>X</td>
</tr>
</tbody>
</table>
As shown by Anton et al. (23), a high-fat diet (40% energy from fat) reduced cravings for carbohydrates at month 12 (P<0.05) and fruit and vegetables at month 24. Additionally, participants reported significant reductions in food cravings for specific types of foods (i.e. high-fat foods, fast food, fats; P<0.05). Conversely, Martin et al. (24) showed that compared with the low carbohydrate diet, the low-fat diet induced significantly larger decreases in cravings for high-fat foods. No evidence was found to support the belief that restricting intake of certain foods could lead to increased craving for these foods (25). The future challenge would be to develop a strategy that diminishes craving for high energy sweets and fast food. The study of Batra et al. (25) hypothesised that subjective hunger and desire for food can change significantly, after 1d over- or underfeeding. Currently, it seems impossible to assess the effectiveness of hunger-suppressing vs. craving-suppressing strategies for obesity therapy.

Sleep in weight regulation

A number of studies have suggested that there is a link between sleep loss and weight gain in adults (26). Physiological studies have shown that sleep deprivation may influence weight through effects on appetite, PA and/or thermoregulation (29). Experimental reductions in sleep duration support the claim that sleeping time could alter metabolic rates or affect the levels of appetite regulatory hormones such as leptin and ghrelin (30). An association between insufficient sleep and increased energy intake has been demonstrated in some studies (29–31).

Sleep restriction was associated with an increase in energy consumption with no change in energy expenditure through PA or leptin and ghrelin concentrations (32). As shown by Nedeltchova et al. (33), bedtime restriction promotes overeating and low activity which was accompanied by increased intake of energy from snacks with higher carbohydrate content without a statistically significant change in the consumption of energy from meals. Markwald et al. (34) found that insufficient sleep increased not only total daily energy expenditure by ∼5%, but also energy intake, especially at night after having finalised the dinner. The increase in energy intake was exceeding the energy needed to maintain the energy balance. The insufficient sleep was leading to 0.82 (sd 0.47) kg weight gain. Recent studies found evidence (35) that sleep deprivation significantly decreases activity in appetite evaluation regions, within the human frontal cortex and insular cortex during food desirability choices, combined with a converse amplification of activity within the amygdala. Another question that is encountered in the clinical setting is whether this bi-directional change in the profile of brain activity is further associated with a significant increase in the desire for weight-gain promoting high-energy foods (35). These findings suggest a role for improving sleep duration as a component of weight management strategy (35).

Effectiveness of energy restriction and macronutrient composition of the diet on regain

The detailed results of intervention studies investigating weight regain identified from the systematic literature search and selected for this review are shown in Table 2. The number of participants in each study was at least 110 and the baseline average BMI in the studied subjects was higher than 35 kg/m². Champagne et al. (39), Kuller et al. (40) and Svetkey et al. (43) included also overweight participants. In the weight loss period, all authors (36–43) applied the reduction of energy intake to at least 5020.8·7531.2 kJ/d (23,40,42,43) even to very low energy diet (41) and with ready-to-use formula (Optifast) (39). The content of fat in the diet was taken into account especially by Wadden et al. (37), Milson et al. (38), Kuller et al. (40) and Svetkey et al. (43). In these studies, consumption under 30% of energy from fat intake was generally taken as goal for the participants. In all studies included in this review article, increase in PA (goal about 180 min/week) was one of the intervention measures, with the exception of the studies performed by Kuller et al. (40) and Lantz et al. (41). Each study conducted the education and dietary counselling for participants as individual as well as group sessions and provided this counselling in different forms, mostly face-to-face but also via email or telephone. Phases of meal replacements were applied in the studies performed by Bischoff et al. (36) and Wadden et al. (37). The measurements of weight gain during follow-up were different across the studies and included direct weight measurements, self-reports of attained weight and assessment of biomarker concentrations. Furthermore, in some studies data on determinants of weight management were also collected. Milsom et al. (38), for example, added a weight management questionnaire to the assessment of weight development after 3.5 years follow-up. The questionnaire results showed that unsuccessful participants were less engaged in record keeping, in regular self-weighing, in planned meals ahead of time and in goal setting sub-scales, e.g. energy, fruit and vegetables, fat. After 3 years, Wadden et al. (37) presented in addition to the results on weight changes also data on self-reported energy intake and energy expenditure (Paffenberger Activity Questionnaire). In this study, the oldest participants (65–76 years) reported lower daily energy intake than younger individuals and men significantly higher weekly energy expenditure from PA and higher energy intake than women. At year 4, intensive lifestyle intervention (ILI) participants achieved a mean loss of 4-7 (se 0.2)% of initial weight, compared with 1-1 (se 0.2)% for individuals in diabetes support and education (P<0.0001). Also Svetkey et al. (43) provided similar data in addition to weight change. Lantz et al. (43) and Bischoff et al. (36), showed only the changes in body weight and BMI after 2-years observation. Champagne et al. (39) presented additionally the changes related to diet by the application of a FFQ. Significant increases from baseline to 6 months were seen in per cent energy from carbohydrate (8·4 (se 0.3)% ) and protein (0·9 (se 0·1)% ), daily dairy servings (0·4 (se 0·03)) and daily...
**Table 2. Long-term weight status after energy restriction and changes in macronutrient composition of the diet**

<table>
<thead>
<tr>
<th>Authors</th>
<th>Population</th>
<th>Duration of intervention</th>
<th>Lifestyle modification</th>
<th>Results</th>
<th>Follow-up</th>
<th>Weight status and used measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bischoff et al.</td>
<td>N = 8296 BMI = 40.8 kg/m² (females) BMI = 35.3 ± 7.7 kg/m² (males)</td>
<td>1-year</td>
<td>The five programme phases included: a) 1-week introduction b) 12-week-period of low-energy diet 3347.2 kJ/d (Optifast 800 formula) c) 6-week-refeeding phase: solid food was reintroduced and formula diet stepwise replaced by normal diet without change of total energy intake d) 7-week stabilisation phase e) 26-week-maintenance phase: nutritional education and behaviour modification (six – medical examinations, thirteen – exercise units, twenty two – behaviour therapy lessons, five – nutrition counselling) Control group: N/R</td>
<td>Weight change from baseline to weight loss phase: −15.2 kg in females and −19.4 kg in males (ITT)</td>
<td>2-year</td>
<td>Assessment: Body weight, body height, BMI. Weight change from baseline to weight regain phase: −5.9 kg (all subjects) Weight gain from weight loss phase to – weight regain phase: +15.1 % (all subjects)</td>
</tr>
<tr>
<td>Wadden et al.</td>
<td>N = 5145 BMI = 36.3 ± 6.2 kg/m² (females) BMI = 36.2 ± 5.7 kg/m² (males)</td>
<td>1-year</td>
<td>Intensive lifestyle intervention (ILI) – Weeks 1–2: energy goal 1200–1800 based on initial weight, with &lt;30 % from fat (&lt;10 % from saturated fat) and a min. of 15 % of from protein. The PA goal: 175 min or more per week Weeks 3–19: liquid meal replacement plan (Slim Fast, Glucerna, Optifast, HMR) Months 7–12: replace one meal and one snack per day with shake and bars; PA &gt;200 min Participants who after 6-months lost: a) &lt;5 % were encouraged to try orlistat b) 10 % &gt;weight loss ≥5 % were eligible for orlistat c) ≥10 % not offered the orlistat. Regained 2 % or more – were allowed to take the orlistat Diabetes support and education (DSE) participants were invited to three group sessions each year – standardised protocols</td>
<td>Weight change from baseline to weight loss phase: ILI −8.7 % v. DSE −0.8 %</td>
<td>3-year</td>
<td>Assessment: Body weight, self-reported energy intake and energy expenditure Weight change from baseline to weight regain phase: ILI: −4.7 % v. DSE: −1.1 % Weight gain from weight loss phase to weight regain phase: ILI: +4 % v. DSE: −0.3 %</td>
</tr>
<tr>
<td>Milsom et al.</td>
<td>N = 110 BMI = 36.76 ± 5.10 kg/m²</td>
<td>0.5-year</td>
<td>Initial 6-month intervention: twenty-four weekly group sessions (90 min). Dietary goals: reduction in: energy intake by 2092–4184 kJ/d, total fats to 25–30 %, and protein to 15 % PA goals: addition of 3000+ steps per day earlier baseline, or 30 min/ d of walking, 6 d/week Control group: N/R</td>
<td>Weight change from baseline to weight loss phase: −10–17 % during the initial six-month intervention</td>
<td>3.5-year</td>
<td>Assessment: Body weight, Weight Management Questionnaire, Weight change from baseline to weight regain phase: N/R Weight gain from weight loss phase to – weight regain phase: +6.95 % from months 6–48</td>
</tr>
<tr>
<td>Champagne et al.</td>
<td>N = 1685 BMI = 25–45 kg/m²</td>
<td>0.5-year</td>
<td>Intervention included twenty weekly, group sessions led by nutrition and behavioral counselors (moderate energy reduction – 2092 kJ/d and PA – 180 min/week) Control group: N/R</td>
<td>Weight change from baseline to weight loss phase: −8–4 kg</td>
<td>2-year</td>
<td>Assessment: Body weight, body height, BMI, FFQ Weight change from baseline to weight regain phase: −4–0 kg Weight gain from weight loss phase to – weight regain phase: +4–4 kg</td>
</tr>
<tr>
<td>Kuller et al.</td>
<td>N = 508 BMI = 25–39.9 kg/m²</td>
<td>0.5-year</td>
<td>Lifestyle Change group (LC) – dietary goals – to reduce: the saturated fat to &lt;7 % of total energy or &lt;10 g/d, energy intake to 5439±2 or 6276±k; to increase the use of foods high in soluble fibre and nutrient-dense, high-volume, low-energetic foods. Health Education group (HE) – six seminars during the first year then several times per year through 36 months.</td>
<td>Weight change from baseline to weight loss phase: LC −7–8 kg v. HE −1–2 kg</td>
<td>4-year</td>
<td>Assessment: Body weight, body height, WC, PA, SBP, LDL-C, HDL-C, TAG, Insulin, Glc, NMR HDL-P, NMR LDL-P, NMR small LDL-P, changes in coronary calcium and carotid plaque Weight change from baseline to weight regain phase: LC −3.4 kg v. HE −0.2 kg Weight gain from weight loss phase to weight regain phase: LC +4–4 kg v. HE +1–0 kg</td>
</tr>
<tr>
<td>Study</td>
<td>Participants</td>
<td>Weight change from baseline to weight loss phase</td>
<td>Weight change from baseline to weight regain phase</td>
<td>Weight gain from weight loss phase to weight regain phase</td>
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<td><strong>Lantz et al.</strong>&lt;sup&gt;(41)&lt;/sup&gt;</td>
<td>N = 113, BMI = 40.2 kg/m²</td>
<td>Very low energetic group: −7.6 kg vs. non-very low energetic group: −6.3 kg (p&lt;ns)</td>
<td>4-year Assessment: Body weight, body height, BMI from weight loss phase to weight regain phase: N/R</td>
<td>N/R</td>
<td>N/R</td>
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<tr>
<td><strong>Lindstroem et al.</strong>&lt;sup&gt;(42)&lt;/sup&gt;</td>
<td>N = 522, BMI = 31.4 ± 4.5 kg/m² (intervention group) BMI = 31.1 ± 4.5 kg/m² (control group)</td>
<td>Intervention group (IG): −4.5 kg vs. CG: −1.0 kg</td>
<td>2-year Assessment: Body weight, waist circumference, fasting plasma glucose, 2-h plasma glucose, HbA1c, TC, HDL-C, TAG, 3-d food record, the validated Kuopio Ischaemic Heart Disease Risk Factor Study 12-month leisure-time physical activity questionnaire Weight change from baseline to weight regain phase: IG: −3.5 kg vs. CG: −0.9 kg</td>
<td>Weight gain from weight loss phase to weight regain phase: IG: +1.0 kg vs. CG: +0.1 kg</td>
<td>N/R</td>
<td></td>
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<tr>
<td><strong>Svetkey et al.</strong>&lt;sup&gt;(43)&lt;/sup&gt;</td>
<td>N = 1029, BMI = 25.1–46.7 kg/m²</td>
<td>Phase 1: behavioural intervention – twenty weekly group sessions Intervention goals: 180 min/week of moderate PA; reduce energetic intake; adopt the Dietary Approaches to Stop Hypertension dietary pattern. Phase 2: Participants randomly assigned to one of three groups: a self-directed condition in which participants received minimal intervention (SD), an interactive technology-based intervention in which participants were encouraged to log on to an interactive Web site; and a personal-contact intervention in which participants had regular, monthly contact with an interventionist (PC)</td>
<td>2-year Weight change from baseline to weight loss phase: 9 SD: −2.9 kg; interactive Web site: −3.3 kg; PC: −4.2 kg (P&lt;0.001)</td>
<td>Weight gain from weight loss phase to weight regain phase: SD: +5.5 kg; interactive Web site: +5.2 kg; PC: +4.0 kg (P&lt;0.001)</td>
<td>N/R</td>
<td></td>
</tr>
</tbody>
</table>

N/R, not reported; PA, physical activity; ITT, intention to treat; WC, waist circumference; ILI, intensive lifestyle intervention; SBP, systolic blood pressure; HbA1c, glycated haemoglobin; TC, total cholesterol; LDL-C, low-density lipoprotein; HDL-C, high-density lipoprotein; Glc, glucose; NMR HDL-P, NMR LDL-P, NMR small LDL-P – proton NMR spectroscopy method for quantifying plasma lipoproteins.
fruit and vegetable servings (3-5 se 0-1)). Other studies(40,42) also included the changes in biomarker concentrations (e.g., LDL-cholesterol, HDL-cholesterol, glucose and insulin). In Lindstrom's study(42) significant improvements were seen at year 1 in fasting plasma glucose (0.2 v. 0.0 mmol/l), 2-h plasma glucose (0.9 v. 0.3 mmol/l), HbA1c (0.1 v. 0.1%), serum total cholesterol to HDL-cholesterol ratio (0.4 v. 0.1), and serum TAG (0.2 v. 0.0 mmol/l) in the intervention group compared with the control group. Additionally, Kuller et al.(48) found that systolic blood pressure (P = 0.048), LDL-cholesterol (P = 0.026), TAG (P = 0.92), insulin (P = 0.0001), glucose (P = 0.002) and HDL-cholesterol (P = 0.0001) developed significantly differently between the Health Education and the Lifestyle Change group. In the reviewed studies, the weight changes from baseline to weight loss ranged from −4 to −0.2 kg: in two studies they were not reported(38,41). However, the studies with no data on weight loss reported an average weight regain of about 4 kg(35–38) and percentage changes in body weight between 4 and 111.5%(36–38). The participants were often re-contacted several times during follow-up, e.g. via emails containing newsletters with information related to weight management.

In the first phase (weight reduction period), the effectiveness of different strategies for weight reduction in obese subjects has been investigated(36–43). It has been shown that similar responses regarding satiety, hunger and satisfaction exist for diets with different proportion of nutrients(44). In general, the reduced-energy diets result in clinically meaningful weight losses regardless of which macronutrients they emphasise(36–44). For long-term weight loss, macronutrient composition should also be considered regarding whether it helps to counteract compensatory mechanisms leading to weight regain after weight loss(45). Thus, interest has been rising for a comparison of different low energy diets containing different ratios of fat, protein and carbohydrates in relation to long-term weight gain. Particular interest was recently given to protein(36,37) and fat(38–40,43). It was found by one group that a high carbohydrate and protein breakfast is preventing weight regain by reducing diet-induced compensatory changes in hunger, cravings and ghrelin suppression(45). High-protein diets may also be related to higher levels of thermogenesis, which can increase energy efficiency during weight loss and help avoiding weight regain(46). It was shown by one study that body-weight loss and low weight-gain depend on the high-protein content of the diet, rather than the low-carbohydrate component, while it is unrelated to the concomitant fat-content of the diet(47). Furthermore, the Mediterranean and Dietary Approaches to Stop Hypertension diet, which was recommended by Champagne et al.(48) and Svetkey et al.(43) for the weight reduction phase, encourages intakes of fruit, vegetables, nuts, and whole grains and discourages intakes of red and processed meats and saturated fat. Unlike the Mediterranean diet, the Dietary Approaches to Stop Hypertension diet, in addition, discourages sodium and sugar-sweetened beverages and encourages the intake of low-fat dairy, and has no specific alcohol recommendation(48). Indeed, the Dietary Approaches to Stop Hypertension diet was related to a reduction in body weight in a high cardiovascular risk population and also prevented weight gain(49,50).

Taking into consideration the age of the participants, as it was expected, younger participants were more familiar with web-based methods and in their case, implementation of web-based methods was a highly effective strategy than older participants, who prefer the traditional methods for information distribution (e.g. newsletter or telephone conferences) and also a manually and simplified form of contact with nutritionist(46,47,42,51–53). In both cases, the face-to-face counselling condition obtained the best results(46,47,51–53). This condition also allowed the study subjects to cope with the new dietary approach in a very short time period. Moreover, the research study should give each of the study participants the opportunity to participate in further behavioural and dietary counselling beyond the scientific study. A key message from the study review is that to build good relations between study subjects and nutritionist, the dietary counselling should be conducted by the same team throughout the study period(36–43). As mentioned previously, clinicians need to emphasise the role of healthy diet for healthy lifestyle.

In the second phase (weight regain phase), the key point seems to be the self-regulation of dietary intake which stays in close connection with changes in dietary habits. It was found in general that individuals who had used a self-guided approach maintained their initial weight loss with great success, even better than those individuals who had used a very low energy diet(36,42). The involvement of study participants in the process of preparing healthy meals might be an important step for obese people, especially in the case when they are losing the motivation to stay slim(54). The study conducted by ter Bogt et al.(55) did not indicate differences in preventing weight gain between structured lifestyle counselling by nurse practitioners compared with usual care by general practitioners in overweight and obese subjects. For the future, it seems to be important not only to record the mean value of weight loss after the intervention period but also focusing on the long-term body weight gain including a more comprehensive documentation of the data during follow-up. In view of the role of dietary changes and their determinants, the documented long-term data on changes in body weight in the studies had been unsatisfactory, particularly in regard to changes in the self-estimation by the study participants(37,38). The available evidence from clinical trials suggests that obese subjects used to perceive themselves as less obese and have a tendency to declare less food intake than actually eaten(56).

### Physical activity and weight regain

The selected studies which integrate the PA into the changes of lifestyle are presented in Table 3. The majority of the studies focused on obese subjects, with the exception of Hunter et al.(49) and Nakade et al.(57) who included both obese and overweight subjects. The studies
### Table 3. Physical activity in long-term weight status

<table>
<thead>
<tr>
<th>Authors</th>
<th>Population</th>
<th>Duration of intervention</th>
<th>Lifestyle modification</th>
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<th>Weight status and used measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunter et al. (49)</td>
<td>N = 208 BMI = 27–30 kg/m²</td>
<td>Time needed to reach the goal of a 25 kg/m² (154 (± 61) d)</td>
<td>I group: diet and aerobic exercise, II group: diet and resistance exercise, III group: diet only (Diet: 3347.2 kJ/d; 20–22 % fat, 18–22 % protein, and 58–62 % carbohydrate, Exercise: three per week during weight loss and two per week during the 1-year following weight loss</td>
<td>Weight change from baseline to weight loss phase: −12.3 kg – no differences between the exercise groups was found (P = 0.2).</td>
<td>1-year</td>
<td>Assessment: Body weight, visceral fat and body fat, WC, BMI, self-administered diet history questionnaire, questionnaire about stages of change to improve lifestyles. Weight change from baseline to weight regain phase: N/R. Weight gain from weight loss phase to weight regain phase: I group: +3.1 kg, II group: +3.9 kg, III group: +6.2 kg.</td>
</tr>
<tr>
<td>Nakade et al. (57)</td>
<td>N = 235 BMI = &gt;28.4 kg/m²</td>
<td>1-year</td>
<td>Intervention group (IG): individual counselling (30 min) and group sessions about effective exercise (20 min) at baseline, 1, 3, 6 and 9 months CG: did not receive support</td>
<td>Weight change from baseline to weight loss phase: IG − 5.0 kg v. CG + 0.1 kg form men and − 4.0 kg v. − 0.2 kg for women, respectively</td>
<td>1-year</td>
<td>Assessment: Body weight, body fat, visceral fat, WC, BMI.</td>
</tr>
<tr>
<td>Borg et al. (58)</td>
<td>N = 90 BMI &gt;30 kg/m²</td>
<td>0-67-year</td>
<td>I Phase: 0-2 months: low-energy diet (5020.8 kJ/d) based on meal-exchange system, and VLED (2092 kJ/d, Nutrilitt), meetings in groups led by a nutritionist II Phase: 2-8 months: weight maintenance two exercise groups trained 45 min three times weekly (energy expenditure (EE): 1255–1673 kJ/session). The subjects were randomised into three groups: a control group (C) with no increase in habitual exercise and two exercise groups (walking, W or resistance training, R) training 45 min three times weekly</td>
<td>Weight change from baseline to weight loss phase: −14.3 kg (all subjects between 0 and 2 months) The subjects in C and W group gained: +1.6 kg and 1.8 kg, respectively, the subjects in R group maintained their weight (+0.3 kg) between 2 and 6 months</td>
<td>1-9-year</td>
<td>Assessment: Body weight, body composition, exercise diaries and dietary records. Weight change from baseline to weight regain phase: N/R. Weight gain from weight loss phase to weight regain phase: C group: +6.8 kg, W group: +8.2 kg, R group: +8.8 kg.</td>
</tr>
<tr>
<td>Jeffery et al. (59)</td>
<td>N = 202 BMI = 31.7 (± 2.6) kg/m²</td>
<td>0-5-year</td>
<td>SBT: an EE goal of 4184 kJ/week, HPA the goal was an EE of 10-46 MJ/week included encouragement to recruit one to three exercise partners into the study, personal counselling from an exercise coach, and small monetary incentives</td>
<td>Weight change from baseline to weight loss phase: SBT: − 8.1 kg v. − 9.0 kg in HPA group</td>
<td>1-year</td>
<td>Assessment: Body weight, PA level – Paffenbarger Physical Activity Questionnaire and dietary intake – the 60-item version of the Block Diet Questionnaire. Weight change from baseline to weight regain phase: SBT: − 4.1 kg v. − 6.7 kg in HPA group. Weight gain from weight loss phase to weight regain phase: SBT: + 4.0 kg v. + 2.3 kg in HPA group.</td>
</tr>
</tbody>
</table>

CG, control group; HPA, high physical activity; N/R, not reported; SBT, standard behaviour therapy; WC, waist circumference; VLED, very-low-energy diet.
were different in PA by demographic characteristics. Participants younger than 50 years, male, non-African American or overweight are more active than those who are older than 50 years, female, African American or obese. Moreover, only 2% of participants are active for 60 or more minutes daily. It should be underlined that sex differences between energy expenditure related to PA, appetite ratings and energy intake may lead to different patterns of energy intake and subsequent weight maintenance.

Very few reviewed intervention studies have explored whether the programmes based on diet and exercise gave better results regarding anthropometry than the use of one method alone. Often the PA is much more difficult to perform by obese subjects, because performance is related to public places. Public places are perceived negatively by this group of subjects, and they are spending ‘extra’ money or finding ‘extra’ time for exercises. In sedentary and obese subjects, it was also found that a supervised exercise-based programme appears to be more efficacious in promoting and maintaining weight loss and improvements in markers of health and fitness compared with an individual counselling and group sessions focused on exercises. It was also observed that both aerobic and resistance training prevented regain of potentially harmful visceral fat. Most likely daily self-monitoring of PA can be one of the feasible and effective approaches for low long-term weight regain. Even 12-months of small-changes of PA due to intervention can be successful in sustaining initial weight loss. Thus, the literature clearly indicates that increased PA is one of the main predictors of low weight status after weight reduction. Increasing PA with increased weight loss might help to maintain weight loss itself. It should be noted that often even moderate weight losses, induced by energy restriction, lead to a large decrease in PA. However, the decrease in PA returns to baseline levels when weight loss is maintained. Thus, clinicians should remind all patients that without maintenance of an active lifestyle, the risk of weight regain is highly increased. The American College of Sports Medicine recommends 150–250 min/week PA to prevent weight gain which should be increased up to 200–300 min/week for prevention of weight gain after weight loss.

Similarly, as in Table 2, in the studies with intervention of PA, only the basic anthropometrical measurements and the energy expenditure during follow-up were assessed, based upon self-administered questionnaires. An implementation of easy to use tools, e.g., accelerometers can be an appropriate mean to favour the maintenance of PA in obese or older adults. In the studies, an intensive lifestyle intervention including high volume of PA resulted in favourable changes in CVD risk factors and eating behaviours in subjects with severe obesity. The lifestyle counselling by either nurses or general practitioners obtained similar results after 3 years intervention in terms of higher PA and healthier diet. Although the studies used different study designs, diet programme and exercise duration, even with a shorter term follow-up, all measures of an increase of PA can be recommended due to its evident beneficial effect on health status.

Conclusions and challenges

In the strategy of successful long-term weight loss among the obese the main role should be given to a diet with self-regulation of dietary intake. This measure should be combined with behaviour therapy and PA and tailored to the individual situation. In addition, the psychosocial condition of the obese subjects stays in close relation to their motivation. However, after having analysed the papers, it is difficult to arrive at a conclusion regarding unambiguous measures related to low long-term weight regain in obese subjects and to recommend a specific dietary intervention.

From the present literature, it appears that more standardised measurements of determinants of weight changes and low weight regain will provide more comparable data and will allow for a better interpretation of the study results. The challenges are seen to harmonise and standardise the data collected in the follow-up period of long-term weight loss studies. The standardised format of data collected in different countries with different languages could give an opportunity for more extensive analysis of existing datasets. Moreover, it appears useful to build up easily accessible programmes for obese subjects after weight loss by an interdisciplinary team that would include nutritional education, individual well-balanced diet, promotion of PA and measures to keep a high motivation of behavioural changes. Regular use of interactive web-sites and potential contact with nutritionist could bring an additional benefit for participants in the follow-up period. Therefore in the process of development of such programmes for obese subjects, all details of the studies conducted so far could be important and should be considered.

Acknowledgements

The authors would like to thank the committee members of the Belgian Nutrition Society, The Nutrition Society and Société Française de Nutrition for allowing the corresponding author to present this paper at the Joint Conference: Sustainable Diet and Food Security, 28–29 May 2013, Lille, France.

Financial Support

None.

Conflicts of Interest

None.

Authorship

M. S. M. and H. B. were the lead authors and involved in all aspects of the review. M. M. and J. W. contributed to writing and editing the article.
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