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Weight regaining: From statistics and behaviors to physiology and metabolism

Costas A. Anastasiou*, Eleni Karfopoulou, Mary Yannakoulia

Department of Nutrition and Dietetics, Harokopio University, Athens, Greece

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ABSTRACT

Achieving maintenance of weight loss is crucial to combat obesity. However, most individuals tend to regain weight. Data from successful maintainers show that they remain vigilant and constantly apply techniques to oppose the course of regaining. On the other hand, current advances in obesity research show that the reduced obese state is a state of altered physiology in terms of energy balance. This review describes the physiological adaptations occurring after weight loss that predispose to regaining. Specifically, changes regarding body composition, hormonal background, energy expenditure and control of food intake are discussed. Moreover, metabolites that can act as regain predictors and dietary techniques to oppose regaining are presented.

1. Introduction

One in three adults in the United States is obese [1]. Overweight and obesity together cover almost 70% of the adult population, justifying the term *obesity pandemic*. Weight loss leads to improvements in obesity comorbidities [2–6], but to consider treatment as effective, results need to be maintained in the long term. Hence, weight loss maintenance constitutes a public health priority.

Most overweight people lose, on average, 5–9% of their initial weight in 6-month period, and this is followed by weight regain [7]. Meta-analyses indicate that five years after completing a structured weight loss program, individuals maintain an average weight loss of 3.2% below initial body weight [8], or, after four years, a 3–6% weight loss, depending on type of weight management intervention [7]. In the Diabetes Prevention Program 10-year follow-up, the lifestyle intervention group was maintaining an average weight loss of just 1 kg below baseline, having regained weight from their initial weight loss of 7 kg during the first year of the study [9]. Recently, in the Look AHEAD study, a weight loss clinical trial involving 5145 individuals with type 2 diabetes, after 8 years of intensive lifestyle intervention including maintenance sessions, weight loss in the intervention group averaged only 4.7% [10]; part of it could be attributed to aging, as the control group also displayed a 2.1% weight reduction at study endpoint. In the intervention arm, 50% of participants managed to maintain a weight loss at least 5% below their initial weight, and 27% maintained a loss at least 10% of their starting weight. Population based studies have also evaluated maintenance rates. In a sample of American adults with maximum BMI ≥ 27 kg/m^2, among those who had achieved

Abbreviations: ACE, angiotensin I converting enzyme; BMI, body mass index; CART, cocaine and amphetamine-regulated transcript; CCK, cholecystokinin; CRP, C-reactive protein; DXA, dual-energy X-ray absorptiometry; FFM, fat-free mass; GLP-1, glucagon-like peptide-1; MCH, melanin-concentrating hormone; NWCR, National Weight Control Registry; NPY, neuropeptide Y; NREE, non-resting energy expenditure; PYY, peptide YY; POMC, pro-opiomelanocortin; REE, resting energy expenditure; TEE, total energy expenditure.

* *Corresponding author at:* Department of Nutrition and Dietetics, Harokopio University, El. Venizelou 70, Athens 17671, Greece. Tel.: +30 210 9549181; fax: +30 210 9549141.
E-mail address: acostas@hua.gr (C.A. Anastasiou).

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weight loss of ≥10%, almost half had maintained this loss for at least one year [11]. In a similar study in Germany, of those who had been overweight/obese and lost ≥10%, 53% were maintaining the loss for over a year [12].

It becomes, thus, evident that weight regaining continues to be a major issue of concern. Even though – and contrary to popular belief – maintenance of weight loss can be achieved, its prevalence remains below satisfactory levels. Those who succeed in long-term weight loss maintenance describe remaining vigilant and constantly applying specific strategies to control their weight, whereas regainers describe discontinuing the effort to regulate body weight [13]. It appears that the "normal" course following weight loss is regaining and possibly weight cycling. Although weight regaining and cycling does not necessarily impede successful participation in diet and/or exercise interventions [14], consistent efforts are needed to oppose it. The present review will examine behavioral and physiological mechanisms and adaptations favoring long-term weigh loss maintenance or weight regaining.

2. Weight Loss Maintenance Behaviors

As evidenced in a series of qualitative and observational studies (and despite their methodological limitations), weight loss maintainers share common lifestyle habits. A common behavior is sustaining an active lifestyle [13,15–19]. In particular, participants of the National Weight Control Registry (NWCR), a US registry of long-term weight loss maintainers, report spending an average of 2621 kcal/week in physical activity, an amount equivalent to more than 60 minutes of moderate intensity exercise each day [20]. Additionally, maintainers continuously report consuming a low-energy diet, with intakes ranging from 1379 to 1700 kcal/day [21,22]. Another pattern among maintainers is regular and frequent self-monitoring of weight; they describe weighing themselves often and also taking corrective action if needed, by adjusting their diet and exercise [13,15–19,23]. Weighing acts as an indicator of energy imbalances, which call for immediate action. NWCR participants who loosened their control over diet and exercise behaviors or decreased their weighing frequency regained more weight compared to those who kept a constant pattern of self-monitoring [23,24].

It should be emphasized that the aforementioned data should be treated with caution since they are based on self-report and thus their accuracy may be questioned. However, these qualitative studies discussed above are still the only source of information available to track common behaviors of successful weight loss maintainers in the long term. Additionally, despite the common behaviors identified, a variety of different behavioral patterns have been reported [25]. Furthermore, maintenance may involve using more strategies for some individuals than others; for example there are maintainers who report less effort in achieving maintenance, or others who do not engage in high levels of exercise [25,26]. Biological factors may interact with environmental influences to facilitate or hinder weight maintenance processes in different ways among individuals.

3. Weight Loss Effects on Body Composition and Energy Expenditure and Potential Implications for Weight Regain

The effects of weight loss on body composition are of interest when studying weight regaining, as fat-free mass (FFM) is a major determinant of 24-h energy expenditure and explains more than 80% of its variance between individuals [27]. During weight loss, a proportion of the weight lost is FFM. This proportion ranges between 14% and 23% of the lost weight for dietary interventions, and can be up to 31% for bariatric surgery [28]. In dietary interventions, a greater degree of caloric restriction leads to greater loss of FFM, whereas exercise inclusion is protective of FFM [28]. In a recent review on weight loss composition, Heymsfield et al. point out that the fraction of weight loss constituting lean mass is larger when baseline fat mass is smaller: When under caloric restriction, the obese who have a larger baseline fat mass will lose relatively less FFM than normal weight subjects [29]. They also concluded that exercise added to a low-calorie diet increases relative fat loss. However, studies are inconclusive on whether aerobic training and resistance training similarly preserve lean mass or resistance training is more beneficial [30–33].

A meta-analysis comparing formerly obese persons and weight-matched controls found that the formerly obese have a higher body fat mass percentage by 2.5% [34]. However, this result should be interpreted with caution, as the included studies were of diverse designs, there was no time definition of weight loss maintenance, meaning that subjects immediately after weight loss could be included, and the formerly obese had slightly but significant higher body weight compared to controls. On the other hand, when body composition was assessed using dual-energy X-ray absorptiometry (DXA) in a subgroup of NWCR reduced-obese subjects, and weight-matched controls who were never obese, results showed no differences between groups in percentage body fat, lean mass or fat mass [35].

Resting energy expenditure (REE) declines by 15 kcal, on average, for every kg of weight lost [36]. In 1995, Leibel et al. demonstrated in a laboratory study that when subjects lose weight, total, resting and non-resting energy expenditure will reduce more than predicted from weight and FFM changes [37]. This phenomenon, i.e. greater reduction in energy expenditure than predicted, is called adaptive thermogenesis and could attribute to weight regain. Evidence of adaptive thermogenesis immediately after weight loss is supported by a number of studies [38–40]. However, studies have yielded mixed results on whether adaptive thermogenesis persists in the maintenance phase. The meta-analysis by Astrup et al. found that reduced-obese subjects had a 3–5% lower REE than control subjects, after adjustments for body composition; however, individual subject meta-analysis, based on individual subject data provided by the researchers, yielded a REE difference of 3% that did not reach statistical significance ($p = 0.09$) [34]. The authors commented that a lower REE could be a consequence of weight loss, or it could precede, and predispose to, the obese state.

In addition, two more studies support the persistence of adaptive thermogenesis during weight loss maintenance. To examine whether metabolic adaptations to weight loss persist over time, Rosenbaum et al. studied, in a closely